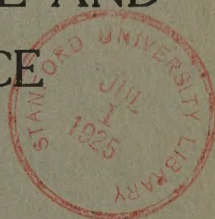


A BIOMETRICAL ANALYSIS OF CHARACTERS OF MAIZE AND OF THEIR INHERITANCE

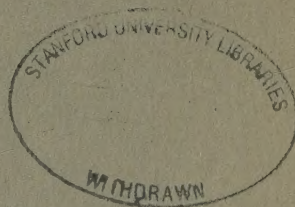


A THESIS

PRESENTED TO THE FACULTY OF THE GRADUATE SCHOOL
OF CORNELL UNIVERSITY FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

By

THOMAS KENNERLY WOLFE, B.S., M.S.



REPRINTED FROM VIRGINIA AGRICULTURAL EXPERIMENT
STATION TECHNICAL BULLETIN No. 26, FEBRUARY, 1924

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CONTENTS

PART I.

	Page
A Study of Ear and Plant Characters of Maize.....	5
Materials and Methods.....	5
Discussion of characters studied.....	7
Ear characters.....	7
Plant characters.....	8
Results.....	8
Constants of variation.....	8
Comparison of the constants of the ear characters.....	11
Comparison of the means.....	11
Comparison of the standard deviations.....	11
Comparison of the coefficients of variation.....	11
Comparison of the constants of the plant characters.....	14
Comparison of the means.....	14
Comparison of the standard deviations.....	14
Comparison of the coefficients of variation.....	14
Correlations.....	14
Coefficients of correlation of the ear characters.....	16
Comparison of the coefficients of correlation of the ear characters.....	18
Coefficients of correlation of the plant characters.....	19
Summary of the correlations.....	20
Linearity of regression.....	20
Analytical constants of variation.....	35
Summary.....	47

PART II.

	Page
The Inheritance of Characters of Maize as Influenced by Hybridization.....	48
Results.....	52
Alvord's Dent X Cornell No. 12.....	52
Comparison of the constants of variation.....	52
Comparison of the means.....	52
Comparison of the standard deviations.....	52
Comparison of the coefficients of variation.....	52
Coefficients of correlation.....	53

Comparison of the correlations between pollen maturity and other characters	53
Comparison of the correlations between weight of grain per stalk and other characters	53
Narrow Leaf X Cornell No. 12	56
Comparison of the constants of variation	56
Comparison of the means	56
Comparison of the standard deviations	56
Comparison of the coefficients of variation	60
Comparison of the coefficients of correlation	60
Summary	60

PART III.

Inheritance of Correlated Characters	62
Material and methods	62
Results	64
Summary	68
Bibliography	68

A BIOMETRICAL ANALYSIS OF CHARACTERS OF MAIZE AND OF THEIR INHERITANCE

By T. K. WOLFE¹

It is desirable in most cases to express the results of investigations in quantitative rather than in qualitative terms. As a result of this desideratum, statistical methods have come into rather wide use in the analysis of plant breeding and other problems. Biometrical methods serve to solve problems and when so used furnish substantial assistance to the investigator. Biometry, as stated by Pearl (1911), brings to the aid of the experimentalist that which is of the utmost importance; namely, an adequate method of describing, analyzing, and of reaching correct conclusions from the results of experimentation.

PART I

A STUDY OF EAR AND PLANT CHARACTERS OF MAIZE

The object of this portion of the investigation is to study statistically certain ear and plant characters in corn in order to analyze more thoroughly the inheritance of these characters. Also, to find out, if possible, the relation of some of the characters to each other as a preliminary step in the planning of certain genetic studies. The correlation coefficients, correlation ratios, linearity of regression, and curve types for many of the characters under observation have been determined.

MATERIAL AND METHODS

In the study of the ear characters the Boone County White variety of corn was used. Ninety ears were taken, some of them would have been classed as good seed ears and some as fair but all were of good size and all were in marketable condition. They were planted in duplicate ear-to-row tests. The hills were 39.6 inches apart each way and each row was twenty hills long. The plants were finally thinned to two stalks to the hill. Thus, in case of a perfect stand and one ear to the stalk there would have been produced forty ears to the row or eighty ears to the duplicate rows. However, the stand was, in practically every case, less than 100 percent but the yields were corrected by determining the percentage of stand. In selecting the ear progenies those were taken, as far as possible, that had about the same number of stalks to the row. After harvest eleven of the high yielding strains and fifteen of the low yielding strains were selected. The next summer data were secured from the ear progenies of the high yielding and the low yielding strains. The details of the methods used and the characters studied will be discussed later.

In case of the plant characters the Silver King variety of corn was used. The seed was secured from an especially selected supply and was planted in hills 39.6

¹Also presented to the Faculty of the Graduate School of Cornell University, as a major thesis in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

inches apart each way. The plants were finally thinned to two stalks to the hill, which, in case of a perfect stand, would allow 8000 stalks to the acre. However, not all hills had two stalks at the time the data were secured and in such cases these hills were discarded. The characters studied and the methods by which the data were obtained will be mentioned later in the paper.

The crops were grown on the experiment plats of the Virginia Agricultural Experiment Station at Blacksburg. The land used produces, on the average, approximately 50 bushels of Boone County White or 45 bushels of Silver King corn to the acre. The crop of Boone County White corn was grown in 1919 and the Silver King variety in 1918 and in 1919. Thus, data were secured in regard to the ear characters for one year and for two years in case of the plant characters.

As has been stated previously a certain number of high yielding and low yielding strains or ears of Boone County White corn were selected in studying the ear characters. This was done in order to study the correlation between certain ear characters of these two strains. If there exists any material correlation between yield and ear characters it would be expected, other things being equal, that the high yielding strains would show a greater degree of correlation than the low yielding strains. The yield of the individual ears of the two strains are shown in Table 1.

Table 1.—Yield in bushels per acre of the high yielding and low yielding strains of Boone County White corn.

Strain	Low yielding strains	High yielding strains
	Bushels	Bushels
1	23.06	47.81
2	24.29	49.33
3	27.10	53.66
4	28.06	53.76
5	28.55	54.69
6	30.80	55.10
7	30.81	55.56
8	30.92	55.65
9	31.61	56.52
10	33.91	59.46
11	35.29	61.43
12	37.51	
13	38.11	
14	38.25	
15	39.09	
Average	31.82	54.82

It will be noted that there is a difference of 8.72 bushels between the highest yielding strain of the low yielding strains and the lowest yielding strain of the high yielding strains. The difference between the average yield of the two groups of strains is 23 bushels.

Later in the paper reference will be made to **marketable ears** and to **random sample**. When the data were secured a notation was made of a certain number of marketable ears of each strain of the low yielding strains. These marketable ears may be classed as the "best" ears of the progeny from a market standpoint. If there is a marked correlation between ear characters and yield, it is probable that correlation coefficients of the marketable ears would be higher than those secured by using

the entire progeny. A comparison of these results is shown later. The labor in calculating results would be lessened to some extent if a random sample of the progeny of each strain could be used instead of the entire progeny. In making the correlation tables the data for each ear were first placed on a card. The cards for the entire progeny of a strain were thoroughly shuffled and one-half of the number of cards removed. The remaining one-half constituted the random sample. This was done in case of the low yielding strains only. The results secured from using the entire progenies and the random sample are shown later in the paper.

Thus, when reference is made to high yielding strains it means that all the ears of these strains were used in making the calculations. This holds also for the low yielding strains. The random sample refers to approximately one-half of the ears of the low yielding strains. The sample was taken from each strain independently after the cards had been shuffled. Marketable ears denote a certain number of the best ears from a market standpoint of each strain of the low yielding strains.

In the investigation the ordinary methods of biometrical analysis were used. A summary of these methods have been given by Elderton (1906), C. B. Davenport (1904), E. Davenport (1907) and Pearl and Surface (1909, 1914). Detailed description of the methods may be found by referring to the work of Pearson and others in the Philosophical Transactions of the Royal Society; Biometrika; and in the Draper's Company Research Memoirs of the Department of Applied Mathematics of University College, London.

DISCUSSION OF CHARACTERS STUDIED

EAR CHARACTERS

Length, Average Circumference of Ear and Average Circumference of Cob.—The measurements were made in inches and taken to the nearest eighth. The average circumference of the ear was determined by measuring the butt end of the ear at one-third the distance toward the tip and the tip end one-third the distance toward the butt and averaging the two. The average circumference of the cob was determined in a like manner after the grain was shelled from the cob.

Ratio of Butt Circumference to Tip Circumference.—This value was calculated by dividing the tip circumference of the ear by the butt circumference of the ear. In this way the shape of the ear was determined. The nearer this ratio approaches unity the more cylindrical is the ear.

Length of Kernel.—In determining this value the average circumference of the cob (b) was subtracted from the average circumference of the ear (a). The length of the kernel was then calculated by the formula $a - b = 2\pi r$ (r =radius or length of kernel). Since a and b are expressed in inches the length of the kernels will be in inches.

Percentage of Grain.—This value was calculated by dividing the weight of shelled grain by the weight of grain and cob.

Number of Rows.—The number of rows on each ear was counted.

Weight of Grain.—The weights were taken in grams to the nearest one-half.

Tip and Butt Values.—These values are arbitrary and are expressed in units from one through ten. Before beginning to collect data ten ears of corn were selected which showed a gradual variation in tip value from very poor to excellent (figure 1).

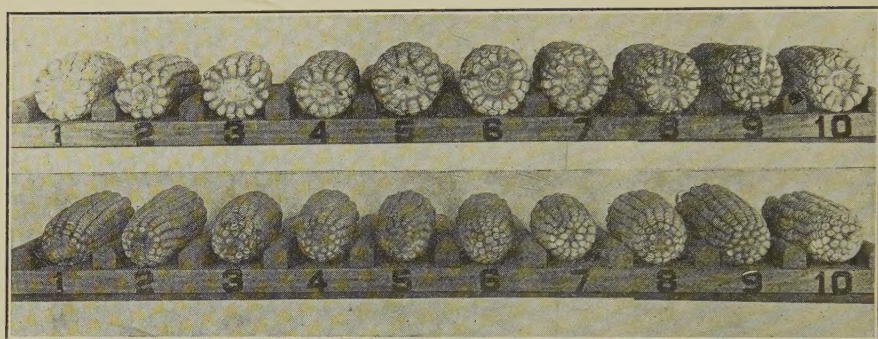


Figure 1.—Showing butts and tips with arbitrary values assigned.

The poorest tip was assigned a value of one and the very best a value of ten. This same method was followed for the butts.

PLANT CHARACTERS

Days to Tasseling and to Silking.—These data were secured by taking daily notes on the time of the appearance of the tassels and silks on the individual stalks.

Average Length and Average Width of Leaf.—The measurements were taken in inches to the nearest eighth. All the leaves on the plants were measured for both length and width, the latter measurement being taken at the place of greatest dimension. The average measurements per plant were secured by dividing the sum of the respective measurements by the total number of leaves per plant.

Height of Stalk Below and Above the Ear.—The measurements were taken in inches. The height below the ear was taken from the ground to the ear. The height above the ear was secured by measuring the distance from the ear to the end of the central branch of the tassel.

Weights of Cob, Stalk and Grain per Stalk.—The weights were taken in grams to the nearest gram except in case of the cob which was weighed to the nearest one-half gram.

Circumference of Stalk.—The measurement was taken in inches to the nearest eighth, below a node. The node selected was the third one below the ear.

Number of Nodes Below and Above the Ear.—These data were obtained by making counts of the nodes in the respective regions. The nodes below the ear were obtained by counting the number from the ground to the ear. In this method there is a chance of error owing to the nodes being very close together at the bottom and the likelihood of some of them being covered by soil during cultivation. It would have been more accurate to have counted the leaves as they appeared to determine the number of nodes.

RESULTS

Constants of Variation.—In a statistical study of the nature presented in this paper it is desirable to calculate some of the constants of variation. From such constants the tendency of the individuals of the different races to deviate from the respective means may be determined. The standard deviations and coefficients of variation for the different characters involved have been determined and in addition

Table 2.—Means, standard deviations, and coefficients of variation for the different ear characters under observation.

Characters		High yielding strains		Low yielding strains		Random sample		Marketable ears	
		M	σ	M	σ	M	σ	M	σ
Length, inches	.....	7.435 $\pm$.041	1.597 $\pm$.029	6.603 $\pm$.040	1.537 $\pm$.023	6.457 $\pm$.053	1.579 $\pm$.041	7.789 $\pm$.032	.844 $\pm$.023
Tip value	.....	2.697 $\pm$.059	2.290 $\pm$.041	2.188 $\pm$.045	1.752 $\pm$.032	2.154 $\pm$.065	1.786 $\pm$.046	2.813 $\pm$.074	1.911 $\pm$.052
Butt value	.....	3.926 $\pm$.048	1.863 $\pm$.034	3.491 $\pm$.052	2.010 $\pm$.037	3.296 $\pm$.072	1.972 $\pm$.051	4.797 $\pm$.063	1.774 $\pm$.043
Average circumference of ear, inches	.....	6.366 $\pm$.017	.670 $\pm$.012	6.129 $\pm$.018	.686 $\pm$.012	6.075 $\pm$.027	.727 $\pm$.019	6.525 $\pm$.020	.508 $\pm$.014
Ratio butt circumference to tip circumference	.....	.935 $\pm$.001	.048 $\pm$.001	.934 $\pm$.001	.052 $\pm$.001	.934 $\pm$.002	.052 $\pm$.001	.926 $\pm$.001	.038 $\pm$.001
Average length of kernel, inches	.....	.411 $\pm$.002	.070 $\pm$.001	.373 $\pm$.002	.074 $\pm$.001	.361 $\pm$.003	.075 $\pm$.002	.409 $\pm$.002	.062 $\pm$.002
Average circumference of cob, inches	.....	3.781 $\pm$.011	.413 $\pm$.007	3.765 $\pm$.012	.450 $\pm$.008	3.744 $\pm$.007	.463 $\pm$.012	3.947 $\pm$.014	.376 $\pm$.010
Percentage of grain	.....	83.424 $\pm$.094	3.656 $\pm$.066	82.200 $\pm$.105	4.080 $\pm$.075	81.852 $\pm$.155	4.226 $\pm$.110	82.914 $\pm$.099	2.576 $\pm$.070
Number of rows	.....	16.234 $\pm$.072	2.794 $\pm$.051	16.140 $\pm$.071	2.732 $\pm$.050	16.200 $\pm$.100	2.740 $\pm$.071	16.826 $\pm$.090	2.324 $\pm$.063
Weight of grain, grams	.....	196.600 $\pm$ 2.074	80.775 $\pm$ 1.467	152.125 $\pm$ 1.806	69.825 $\pm$ 1.277	144.925 $\pm$ 2.599	70.850 $\pm$ 1.838	210.875 $\pm$ 1.736	44.950 $\pm$ 1.227
Length, inches	.....	21.48 $\pm$ 4.38	1.597 $\pm$.029	23.26 $\pm$ 4.43	1.537 $\pm$.023	24.45 $\pm$.671	1.579 $\pm$.041	10.83 $\pm$.299	.844 $\pm$.023
Tip value	.....	84.91 $\pm$ 2.409	2.290 $\pm$.041	80.07 $\pm$ 2.212	1.752 $\pm$.032	82.91 $\pm$ 3.314	1.786 $\pm$.046	67.93 $\pm$ 2.573	1.911 $\pm$.052
Butt value	.....	47.45 $\pm$ 1.038	1.863 $\pm$.034	57.58 $\pm$ 1.358	2.010 $\pm$.037	59.83 $\pm$ 2.033	1.972 $\pm$.051	36.98 $\pm$ 1.140	1.774 $\pm$.043
Average circumference of ear, inches	.....	10.52 $\pm$.193	.670 $\pm$.012	11.19 $\pm$.207	.686 $\pm$.012	11.97 $\pm$ 3.15	.727 $\pm$.019	7.78 $\pm$.212	.508 $\pm$.014
Ratio butt circumference to tip circumference	.....	.513 $\pm$.093	.048 $\pm$.001	.557 $\pm$.102	.052 $\pm$.001	5.57 $\pm$.144	.052 $\pm$.001	4.10 $\pm$.112	.038 $\pm$.001
Average length of kernel, inches	.....	17.03 $\pm$ 3.13	.413 $\pm$.007	19.84 $\pm$ 3.77	.450 $\pm$.008	20.38 $\pm$.550	.463 $\pm$.012	15.16 $\pm$.423	.376 $\pm$.010
Average circumference of cob, inches	.....	10.92 $\pm$.201	3.656 $\pm$.066	11.95 $\pm$.222	4.080 $\pm$.075	12.37 $\pm$.526	4.226 $\pm$.110	9.53 $\pm$.260	2.576 $\pm$.070
Percentage of grain	.....	4.38 $\pm$.079	2.794 $\pm$.051	4.96 $\pm$.051	2.732 $\pm$.050	5.16 $\pm$.134	2.740 $\pm$.071	3.11 $\pm$.085	2.324 $\pm$.063
Number of rows	.....	17.21 $\pm$.322	80.775 $\pm$ 1.467	16.93 $\pm$.313	69.825 $\pm$ 1.277	16.91 $\pm$.451	70.850 $\pm$ 1.838	13.81 $\pm$.384	44.950 $\pm$ 1.227
Weight of grain, grams	.....	41.08 $\pm$.863		45.90 $\pm$ 1.001		43.89 $\pm$ 1.542		21.31 $\pm$.603	

to these constants of variation the means have been calculated. As is discussed later, in some instances the standard deviation is a satisfactory measure of the variation of characters from the mean. In other instances the coefficient of variation is the more desirable measure, especially when the means differ greatly.

The means, standard deviations, and coefficients of variation for the ear characters are given in Table 2 and for the plant characters in Table 4. When percentage of grain, relative, was correlated with other characters, the random sample used was not the same as the random sample referred to elsewhere in the paper. Both of the random samples were taken from the low yielding strains in the same manner but at different times. The means, standard deviations, and coefficients of variation of the characters used in the correlation with the percentage of grain are given in Table 3.

Table 3.—Means, standard deviations and coefficients of variation for the characters correlated with percentage of grain as relative.

Characters	M	σ	C
Tip value	2.273 $\pm$.067	1.843 $\pm$.043	83.66 $\pm$ 3.352
Butt value	3.423 $\pm$.074	2.023 $\pm$.052	59.10 $\pm$ 1.993
Average length of kernel, inches	.371 $\pm$.003	.079 $\pm$.002	21.29 $\pm$.575
Average circumference of cob, inches	3.769 $\pm$.017	.460 $\pm$.012	12.20 $\pm$.320
Percentage of grain	81.860 $\pm$.116	4.528 $\pm$.117	5.53 $\pm$.143

Table 4.—Means, standard deviations, and coefficients of variation for the different plant characters under observation.

Characters in 1918	M	σ	C
Days to silking	76.880 $\pm$.138	3.764 $\pm$.097	4.89 $\pm$.127
Days to tasseling	65.688 $\pm$.163	4.468 $\pm$.115	6.79 $\pm$.176
Average length of leaf, inches	27.188 $\pm$.094	2.572 $\pm$.067	9.46 $\pm$.245
Average width of leaf, inches	3.714 $\pm$.016	.448 $\pm$.012	12.06 $\pm$.317
Number of nodes below ear	5.628 $\pm$.037	1.003 $\pm$.026	17.82 $\pm$.476
Number of nodes above ear	5.584 $\pm$.026	.713 $\pm$.018	12.77 $\pm$.336
Height of stalk below ear, inches	31.408 $\pm$.279	7.608 $\pm$.197	24.22 $\pm$.663
Height of stalk above ear, inches	50.544 $\pm$.282	7.704 $\pm$.120	15.24 $\pm$.404
Weight of grain per stalk, grams	191.500 $\pm$ 1.686	46.020 $\pm$ 1.192	24.03 $\pm$.657

Table 4 (Continued).—Means, standard deviations, and coefficients of variation for the different plant characters under observation.

Characters in 1919	M	σ	C
Days to silking	77.208 $\pm$.140	4.082 $\pm$.099	5.29 $\pm$.129
Days to tasseling	67.610 $\pm$.123	3.574 $\pm$.087	5.29 $\pm$.129
Average length of leaf, inches	26.260 $\pm$.086	2.506 $\pm$.061	9.54 $\pm$.232
Average width of leaf, inches	3.530 $\pm$.016	.459 $\pm$.011	13.00 $\pm$.322
Number of nodes below ear	4.841 $\pm$.036	1.059 $\pm$.026	21.87 $\pm$.557
Number of nodes above ear	5.412 $\pm$.026	.759 $\pm$.018	14.02 $\pm$.348
Height of stalk below ear, inches	22.816 $\pm$.220	6.400 $\pm$.156	28.05 $\pm$.734
Height of stalk above ear, inches	43.936 $\pm$.293	6.520 $\pm$.207	19.39 $\pm$.489
Weight of cob, grams	28.750 $\pm$.376	10.920 $\pm$.266	37.98 $\pm$.049
Weight of stalk, grams	110.520 $\pm$ 1.270	36.900 $\pm$.898	33.39 $\pm$.899
Circumference of stalk, inches	2.579 $\pm$.012	.340 $\pm$.008	13.18 $\pm$.326
Weight of grain per stalk, grams	147.500 $\pm$ 1.790	52.020 $\pm$ 1.266	35.27 $\pm$.959

Comparison of the Constants of the Ear Characters.—The differences between the means, standard deviations, and coefficients of variation of the high yielding strains and low yielding strains, low yielding strains and the random sample, and the low yielding strains and the marketable ears with their probable errors are given in Tables 5-7. Also, the ratio of the difference in each instance. These tables will be discussed on the basis that the difference must be at least 3.2 times its probable error before it is significant. When the constant exceeds the probable error by this amount the odds are approximately 30 to 1 that such a difference is not due to the errors of random sampling. If the odds are less than this amount the results are not usually considered significant, Wood and Stratton (1910).

Comparison of the Means.—In considering the means, Table 5, it will be seen that those of the high yielding strains are larger in every instance than those of the low yielding strains. However, in three instances, ratio of butt circumference to tip circumference, average circumference of cob, and number of rows, the differences are not significant. The greatest differences are shown in the cases of weight of grain, length of ear, and average length of kernel. This comparison brings out that those strains which have yielded the highest, in most instances, have the highest mean values for the score card points considered.

Since the random sample and marketable ears are samples of the low yielding strains, these three samples are comparable. In considering the low yielding strains and the random sample it will be found that in case of all characters, except number of rows, the low yielding strains have higher means than the random sample. It is to be noted further, however, that in no instance is the difference significant. This indicates that the random sample used was a representative one. This relation between the random sample and the low yielding strains will be found to hold in every instance considered in this paper. Such results indicate that a fair random sample will give as accurate conclusions from the individuals concerned as the entire sample.

In comparing the means of the low yielding strains and the marketable ears it will be found that, with exception of the ratio of butt circumference to tip circumference, the values for the marketable ears are higher than those for the random sample. The differences in all instances are significant when compared with their probable errors. This difference would, other things being equal, be expected since the marketable ears are a selected lot.

Comparison of the Standard Deviations.—The differences in the standard deviations of the various samples are given in Table 6. It will be seen that in six instances the values are higher for the low yielding than for the high yielding strains, but for two of the characters the differences are not pronounced. In four cases the standard deviations are higher for the high yielding strains, but the differences are not significant for two of the characters.

The values for eight of the characters are higher for the random sample than for the low yielding strains in case of the standard deviations. In another instance there is no difference, while for butt value the constant is greater for the low yielding strains. It will be noted that in no instance are the differences very decided.

There is less variation in case of the marketable ears, as shown by the standard deviations, than in case of the low yielding strains with exception of tip value, but here the difference is not pronounced. In all other instances, with exception of average circumference of cob, the differences are significant.

Comparison of the Coefficients of Variation.—As shown in Table 6 variation has been expressed by means of the standard deviation. This constant gives an absolute expression of variability while the coefficient of variation, Table 7, is a relative ex-

Table 5.—Comparison of the means of the ear characters of the various samples.

Characters	High yielding strains minus low yielding strains		Low yielding strains minus random sample		Low yielding strains minus marketable ears	
	Difference	D/E	Difference	D/E	Difference	D/E
Length, inches						
Tip value	.827 ± .057	14.509	.151 ± .070	2.157	-.1181 ± .051	23.157
Butt value	.509 ± .074	6.878	.034 ± .079	.430	-.625 ± .087	7.184
Average circumference of ear, inches	.435 ± .071	6.127	.195 ± .089	2.191	-.1306 ± .086	15.186
Ratio butt circumference to tip circumference	.237 ± .025	9.480	.054 ± .032	1.637	-.396 ± .027	14.667
Average length of kernel, inches	.001 ± .001	1.000	0 ± .002	0	.098 ± .001	8.000
Average circumference of cob, inches	.038 ± .003	12.667	.005 ± .004	1.250	-.036 ± .003	12.000
Percentage of grain	.016 ± .016	1.000	.021 ± .021	1.000	-.182 ± .018	10.111
Number of rows	1.224 ± .141	8.681	.343 ± .187	1.861	-.714 ± .144	4.958
Weight of rows	.094 ± .101	.931	-.060 ± .123	.488	-.696 ± .115	5.965
Weight of grain, grams	44.475 ± 2.750	16.173	7.200 ± 3.165	2.275	-58.750 ± 2.505	23.453

Table 6.—Comparison of the standard deviations of the ear characters of the various samples.

Characters	High yielding strains minus low yielding strains		Low yielding strains minus random sample		Low yielding strains minus marketable ears	
	Difference	D/E	Difference	D/E	Difference	D/E
Length, inches						
Tip value	.060 ± .040	1.500	-.042 ± .050	.840	.693 ± .036	19.250
Butt value	.538 ± .052	10.346	-.034 ± .056	.607	-.159 ± .061	2.607
Average circumference of ear, inches	.147 ± .050	2.940	.038 ± .063	.603	.236 ± .061	3.869
Ratio butt circumference to tip circumference	-.016 ± .017	.941	-.041 ± .022	1.864	.178 ± .018	9.889
Average length of kernel, inches	-.004 ± .001	4.000	0 ± .001	0	.014 ± .001	14.000
Average circumference of cob, inches	-.004 ± .001	4.000	-.001 ± .002	.500	.012 ± .002	6.000
Percentage of grain	-.037 ± .011	3.364	-.013 ± .014	.929	.074 ± .033	2.242
Number of rows	-.424 ± .100	4.240	-.146 ± .133	1.098	1.504 ± .103	14.602
Weight of rows	.062 ± .071	.973	-.008 ± .087	.453	.408 ± .080	5.100
Weight of grain, grams	10.950 ± 1.945	5.630	-1.025 ± 2.238		24.875 ± 1.771	14.046

Table 7.—Comparison of the coefficients of variation of the ear characters of the various samples.

Characters	High yielding strains minus low yielding strains		Low yielding strains minus random sample		Low yielding strains minus marketable ears	
	Difference	D/E	Difference	D/E	Difference	D/E
Length, inches	-1.78 ± .606	2.937	-1.19 ± .807	1.475	12.43 ± .539	23.061
Tip value	4.84 ± 3.271	1.480	-2.84 ± 3.984	.713	12.14 ± 3.393	3.578
Butt value	-10.13 ± 1.709	5.927	-2.25 ± 2.445	.920	20.60 ± 1.773	11.659
Average circumference of ear, inches	-.67 ± .283	2.367	-.78 ± .377	2.069	3.41 ± .296	11.520
Ratio butt circumference to tip circumference*	-.44 ± .138	3.188	0 ± .176	0	1.47 ± .151	9.735
Length of kernel inches	-2.81 ± .493	5.700	-.54 ± .667	.810	4.68 ± .567	8.254
Circumference of cob, inches	-1.03 ± .299	3.445	-.42 ± .394	1.066	2.42 ± .342	7.076
Percentage of grain	-.58 ± .121	4.793	-.20 ± .162	1.235	1.85 ± .125	14.800
Number of rows	.28 ± .453	.618	-.02 ± .552	.036	3.12 ± .499	6.259
Weight of grain, grams	-4.82 ± 1.322	3.646	-2.99 ± 1.838	1.627	24.39 ± 1.171	20.999

Table 8.—Comparison of the means, standard deviations, and coefficients of variation of the plant characters, 1918 minus 1919.

Characters	M		σ		C	
	Difference	D/E	Difference	D/E	Difference	D/E
Days to silking	-.328 ± .197	1.665	-.318 ± .139	2.288	-.40 ± .181	2.210
Days to tasseling	-1.922 ± .204	9.422	-.884 ± .144	6.139	1.50 ± .218	6.881
Average length of leaf, inches	.928 ± .127	7.307	-.66 ± .091	.725	-.08 ± .337	.237
Average width of leaf, inches	.184 ± .023	8.000	-.011 ± .016	.687	-.94 ± .452	2.080
Number of nodes below the ear	.787 ± .052	15.135	-.056 ± .037	1.514	-4.05 ± .733	5.525
Number of nodes above the ear	.172 ± .037	4.649	-.046 ± .025	1.840	-1.25 ± .153	8.170
Number of stalks below the ear, inches	8.592 ± .355	24.203	1.208 ± .251	4.813	-3.83 ± .989	3.873
Height of stalk below the ear, inches	6.608 ± .407	16.236	-.816 ± .229	3.414	-4.15 ± .634	6.546
Height of stalk above the ear, inches	44.000 ± 2.459	17.893	-6.000 ± 1.739	3.450	-11.24 ± 1.162	9.673
Weight of grain, grams						

pression. The standard deviation is expressed in units of measurement and the coefficient of variation in percentage. Since the latter expression is relative, a variable character whose data have been recorded in inches is directly comparable with another whose data have been measured in grams. The standard deviation may be used to make direct comparison of the variability of different lots of the same kind of data measured in the same units.

It will be seen from Table 7 that the characters of the low yielding ears are more variable in eight cases than those of the high yielding ones. The reverse is true in the other two instances. In four instances the differences would not be considered significant; namely, length of ear, tip value, circumference of ear, and number of rows. These results as well as those of the standard deviations show that, on the whole, the characters of the low yielding strains are more variable than those of the high yielding strains. In other words, the individuals of the latter strains deviate less from the mean of the total population than those of the former strains.

The coefficients of variation are greater for eight of the characters of the low yielding strains when compared with the random sample. In one instance there is no difference and the differences for the other characters is slightly in favor of the low yielding strain. It will be noted that the differences are not decided in any case.

In comparing the low yielding strains and the marketable ears it will be found that the coefficients of variation are significantly greater for the low yielding strains for all characters. It seems that the characters of the marketable ears are the least variable of any of the four samples studied. This condition is to be expected since the sample is a selected lot of individuals. The extreme individuals are the ones which vary most widely from the mean and in this sample those much below the mean of the original population have been eliminated.

Comparison of the Constants of the Plant Characters.—A comparison of the means, standard deviations and coefficients of variation for the plant characters may be found in Table 8.

Comparison of the Means.—In studying the means it will be seen that they are larger for seven characters in 1918 than in 1919 while in two cases the reverse is true. The differences are significant for all characters except for days to silking. It would seem, therefore, that the conditions for growth and development were more favorable in 1918 than in 1919.

Comparison of the Standard Deviations.—The standard deviations are greater in 1919 for six characters while for three characters the reverse is shown. The differences in five instances are not marked. It has been found by Love and Leighty (1914) in the case of oats that as the means decrease the variability decreases. This condition apparently was not obtained in case of the plant characters of corn.

Comparison of the Coefficients of Variation.—The coefficients of variation are greater in 1919 for all characters, except one, days to tasseling. The differences are significant except for days to silking, average length of leaf, and average width of leaf.

The most variable characters of the plant as denoted by the coefficients of variation, Table 4, are weight of cob, weight of grain, weight of stalk, height of stalk below the ear, and number of nodes below the ear. The least variable plant characters are days to silking and tasseling.

Correlations.—The coefficients expressing the correlation between the different ear characters under observation are given in Table 9. Many of the characters given

Table 9.—Coefficients of correlation between the different ear characters under observation.

Weight of grain in grams, relative, correlated with	High yielding strain	Low yielding strains
Length, inches	.873 ± .006	.878 ± .006
Tip value	.558 ± .018	.366 ± .022
Butt value	.621 ± .016	.649 ± .015
Ratio butt circumference to tip circumference	.775 ± .010	.794 ± .009
Average length of kernel, inches	— .140 ± .025	— .010 ± .026
Average circumference of cob, inches	.659 ± .014	.689 ± .013
Percentage of grain	.536 ± .018	.516 ± .019
Number of rows	.287 ± .023	.309 ± .023
	.251 ± .024	.375 ± .022
Percentage of grain, relative, correlated with		
Tip value	.175 ± .025	.122 ± .025
Butt value	.251 ± .024	.215 ± .025
Average length of kernel, inches	.444 ± .021	.485 ± .020
Average circumference of cob, inches	— .130 ± .025	— .113 ± .025

Table 9 (Continued).—Coefficients of correlation between the different ear characters under observation.

Weight of grain in grams, relative, correlated with	Random sample	Marketable ears
Length, inches	.877 ± .008	.675 ± .021
Tip value	.293 ± .033	.267 ± .036
Butt value	.646 ± .021	.292 ± .035
Ratio butt circumference to tip circumference	.793 ± .014	.669 ± .021
Average length of kernel, inches	— .047 ± .037	.001 ± .039
Average circumference of cob, inches	.739 ± .017	.533 ± .028
Percentage of grain	.502 ± .027	.334 ± .034
Number of rows	.353 ± .032	.206 ± .037
	.322 ± .033	.236 ± .036
Percentage of grain, relative, correlated with		
Tip value	.174 ± .035	.053 ± .038
Butt value	.246 ± .034	.152 ± .038
Average length of kernel, inches	.525 ± .026	.383 ± .033
Average circumference of cob, inches	— .105 ± .036	— .277 ± .036

in Table 9 are usually considered in judging corn by the use of the score card. The score card for corn is based on an ideal type of ear. In comparatively recent times there has been much criticism of the score card as a basis for selecting high yielding strains of corn. Much data have been presented to show that there is apparently no consistent relation between any of the score card points and yield. Such results have been obtained by Biggar (1919), Cunningham (1916), Love (1912), Love and Wentz (1917), McCall and Wheeler (1913), Montgomery (1909), Olson, Bull and Hayes (1918), Pearl and Surface (1910), Williams and Welton (1915). The work of Hutcheson and Wolfe (1918) substantiates the foregoing investigations for many characters but in some instances it does not.

If the correlation between yield and certain score card points of the corn ear are of sufficient magnitude to be significant, then, other things being equal, high yielding strains of a variety should have decidedly higher coefficient of correlation than low yielding strains of the same variety. These high and low yielding strains or

ear progenies can be determined by the ear-to-row-test. Also, if the correlations of the ear characters with yield are significant, it is to be expected that the largest or marketable ears of a particular lot of corn will give higher coefficients than those obtained from the entire lot. However, this may not necessarily hold, for ears may be marketable and still not approach the ideal type of ear from the score card standpoint.

The mass of data indicates that there should be a radical change in the score card points before the score card will be of greatest value in serving as an aid in corn improvement. Because there are certain characters usually listed on corn score cards which are not apparently correlated with yield scarcely justifies discarding the score card in its entirety. It may be that some of the characters not correlated with yield indicate a certain type or selection in a certain direction. The use of such characters may be justified so long as they do not reduce the yield. No practical corn grower will select corn for seed on the basis of one or two ear characters alone, but on the basis of several characters, provided the score card is used at all.

The coefficients expressing the correlation between the plant characters under observation are given in Table 10. A knowledge of the relationship existing be-

Table 10.—Coefficients of correlation between different plant characters under observation.

Weight of grain in grams per stalk, relative, correlated with	1918	1919
Days of silking	— .180 ± .035	— .452 ± .027
Days to tasseling	— .142 ± .036	— .277 ± .032
Average length of leaf, inches	.363 ± .032	.491 ± .026
Average width of leaf, inches	.412 ± .030	.591 ± .022
Number of nodes below ear	.334 ± .032	.349 ± .030
Number of nodes above ear	.202 ± .035	.181 ± .033
Height of stalk below ear, inches	.356 ± .032	.423 ± .028
Height of stalk above ear, inches	.177 ± .035	.093 ± .034
Weight of cob, grams		.732 ± .016
Weight of stalk, grams		.669 ± .019
Circumference of stalk, inches		.653 ± .020
Height of stalk below ear in inches, relative, correlated with		
Height of stalk above ear, inches	— .263 ± .034	.149 ± .034

tween the different characters of the corn plant is very important. Such a knowledge may be of great economic value in selecting better seed and in other ways.

Coefficients of Correlation of the Ear Characters.—Where weight of grain, Table 9, has been correlated with the various characters studied it will be found that the coefficients of correlation for the marketable ears are the lowest of any of the samples. The coefficients of the high yielding and the low yielding strains agree rather closely. Also, the correlation values of the low yielding strains and those of their random sample are in close accord. Such results tend to indicate that by the use of the score card alone high yielding strains or ears of corn cannot be discovered. With exception of the ratio of butt circumference to tip circumference (cylindricity of the ear) there seems to be rather high positive correlation where weight of grain has been correlated with the various characters studied. It is to be noticed that the coefficients of correlation of weight of grain with percentage of grain and with number of rows is smaller than the other coefficients with the exception of ratio of

butt circumference to tip circumference. The coefficients are as a whole higher than those which have usually been reported. It seems that with most of the score card characters studied there is a rather significant correlation with weight of grain. However, it seems that the coefficients of the low yielding ears are just as significant as those of the high yielding ears. This indicates that if the score card is used it must be done in connection with some performance test of the ears scored. At this time the ear-to-row test seems to be the most satisfactory method for comparing yields of different strains and varieties of corn. It must not be overlooked that these results indicate significant correlations of weight of grain with most of the score card characters studied. If it may be assumed that weight and other characters of the seed ear are correlated with yield, then the score card may be of value

Table 11.—Comparison of the coefficients of correlation for the characters of the various samples.

Weight of grain in grams, relative, correlated with	High minus low yielding strains	
	Difference	D/E
Length, inches	-.005 ± .008	.625
Tip value	.192 ± .028	6.857
Butt value	-.028 ± .022	1.273
Average circumference of ear, inches	-.019 ± .013	1.462
Ratio butt circumference to tip circumference	.130 ± .036	3.611
Average length of kernel, inches	-.030 ± .019	1.579
Average circumference of cob, inches	.020 ± .026	.769
Percentage of grain	-.022 ± .033	.667
Number of rows	-.124 ± .033	3.758
Percentage of grain, relative, correlated with		
Tip value	.053 ± .035	1.514
Butt value	.036 ± .035	1.029
Average length of kernel, inches	-.041 ± .029	1.414
Average circumference of cob, inches	.017 ± .035	.486

Table 11 (Continued).—Comparison of the coefficients of correlation for the characters of the various samples.

Weight of grain in grams, relative, correlated with	Low yielding strains minus random sample	
	Difference	D/E
Length, inches	.001 ± .010	.100
Tip value	.073 ± .040	1.825
Butt value	.003 ± .026	.115
Average circumference of ear, inches	.001 ± .017	.059
Ratio butt circumference to tip circumference	.037 ± .045	.822
Average length of kernel, inches	-.050 ± .021	2.381
Average circumference of cob, inches	.014 ± .033	.424
Percentage of grain	-.044 ± .039	1.128
Number of rows	.053 ± .040	1.325
Percentage of grain, relative, correlated with		
Tip value	-.052 ± .043	1.209
Butt value	-.031 ± .042	.738
Average length of kernel, inches	-.040 ± .033	1.212
Average circumference of cob, inches	.008 ± .044	.182

Table 11 (Continued).—Comparison of the coefficients of correlation for the characters of the various samples.

Weight of grain in grams, relative, correlated with	Low yielding strains <i>minus</i> marketable ears	
	Difference	D/E
Length, inches	.203±.022	9.227
Tip value	.099±.042	2.357
Butt value	.357±.038	9.395
Average circumference of ear, inches	.125±.023	5.435
Ratio butt circumference to tip circumference	— .011±.047	.234
Average length of kernel, inches	.156±.031	5.032
Average circumference of cob, inches	.182±.039	4.667
Percentage of grain	.103±.044	2.341
Number of rows	.139±.042	3.310
Percentage of grain, relative, correlated with		
Tip value	.069±.045	1.533
Butt value	.063±.045	1.490
Average length of kernel, inches	.102±.039	2.615
Average circumference of cob, inches	— .164±.044	3.727

in selecting seed ears from those strains of corn which are known to be of superior yielding power. The work of Love (1912), Love and Wentz (1917), McCall and Wheeler (1913), Olson, Bull and Hayes (1918), Pearl and Surface (1910), Williams and Welton (1915) and others indicate that there is no consistent relation between the characters of the seed ear and yield of grain per plant.

It may be seen in Table 5 that the mean weight of grain of the high yielding strains exceeds that of the low yielding strains by 44.475 ± 2.750 grams. This difference is 16.173 times the probable error and is, therefore, very significant. From such data it seems that weight of grain is correlated with yield. It is shown in Table 9 that in all cases where weight of grain per ear has been correlated with other characters the coefficients are significantly positive except for ratio of butt circumference to tip circumference. This holds for both the high yielding and low yielding strains. When the differences in the coefficients of correlation of these two strains are considered it will be found from Table 11 that in only three instances are the differences marked. These instances are; namely, tip value, ratio butt circumference to tip circumference, and number of rows. It would seem from such results that by the use of the score card alone high and low yielding strains of corn cannot be determined. However, within strains the score card may be of value in selecting the high yielding ears. In this investigation, as well as that of Hutcheson and Wolfe (1918) the yield has been secured and the ears scored from the same crop. In other words, all data have been taken from corn grown in one season. In the case of Love, and Love and Wentz and the other investigators cited above, the seed ears have been scored and planted and the characters of the seed ears correlated with yield per plant. The results secured, therefore, represent those of the two crops.

Comparison of the Coefficients of Correlation of the Ear Characters.—A comparison of the coefficients of correlation of the high yielding and low yielding strains in regard to weight of grain is given in Table 11. It will be found that for six characters the coefficients are higher for the low yielding strains. In case of the other three characters the reverse is true. In three cases only are the differences pronounced; namely, tip value, ratio of butt circumference to tip circumference, and number of rows. In studying the correlation of percentage of grain with other char-

acters of these same two strains, three of the values are higher for the characters of the high yielding strains while in the other case the value for the low yielding strains is higher. In no instances are the differences great. These results indicate that on the whole there is but little difference between the coefficients of the high and low yielding strains.

In comparing the coefficients of the low yielding strains and random sample where weight of grain has been correlated with other characters it will be found that for seven characters the values are higher for the low yielding strains. The differences are not decided in any case. Where the percentage of grain has been correlated with other characters in three of the four characters the values are higher for the random sample. In none of the instances are the differences significant. Such results are to be expected of a fair random sample involving sufficient individuals.

In studying the coefficients of correlation of the low yielding strains and marketable ears it is shown that the values are higher for the low yielding strains, except in case of the ratio of butt circumference to tip circumference. The differences are significant, except for tip value, ratio of butt circumference to tip circumference, and percentage of grain. Where percentage of grain has been correlated with other characters the values are higher for the low yielding strains, except for average circumference of cob; and, this is the only difference which is marked. It seems that to secure accurate results selected ears should not be used but instead either the entire sample or, as has been previously shown, a random sample.

Coefficients of Correlation of the Plant Characters.—The coefficients of correlation of yield with certain plant characters are given in Table 10. It will be found, Table 12, that the value are higher in 1919 than in 1918 except for height of stalk

Table 12.—Comparison of the coefficients of correlation for the plant characters, 1918 minus 1919

Yield of grain in grams per stalk, relative, correlated with	Difference	D/E
Number of days to silking	— .272 ± .044	6.182
Number of days to tasseling	— .135 ± .043	2.812
Average length of leaf, inches	— .128 ± .041	3.122
Average width of leaf, inches	— .179 ± .037	4.838
Number of nodes below the ear	— .015 ± .044	.341
Number of nodes above the ear	— .021 ± .048	.437
Height of stalk below the ear, inches	— .067 ± .043	1.558
Height of stalk above the ear, inches	.084 ± .049	1.714
Height of stalk below the ear in inches, relative, correlated with		
Height of stalk above the ear, inches	— .412 ± .048	8.583

above the ear. It is shown that in three instances only are the differences significant; namely, number of days to silking, average width of leaf, and probably average length of leaf. There is a marked difference in the correlation of height of stalk below the ear with height of stalk above the ear, the value being higher in 1919. No definite conclusion can be drawn from such meagre data as to the relation of the height of stalk below the ear to that above the ear.

Summary of the Correlations.—As shown in Table 9, the highest coefficients of correlation with weight of grain were secured in the case of length of ear, average circumference of ear, average length of kernel, and butt value in the order named. The coefficients of ratio of butt circumference to tip circumference with weight of grain are negative in three of the four samples. The coefficients are not significant in any of the four samples except possibly that of the high yielding strains where the coefficient is $-.140 \pm .025$. These figures indicate there is either no relation between weight of grain and cylindricity or that more tapering the ear the greater will be the weight of grain.

Percentage of grain was correlated with tip value, butt value, average length of kernel, and average circumference of cob. The correlation with tip value is small but positive, while that with butt is positive and more marked. There is a fair degree of correlation of percentage of grain with length of kernel. The correlation with average circumference of cob is small and negative in all four samples. These results indicate that the larger the cob and shorter the kernels the smaller the percentage of grain.

The coefficients expressing the correlation between the different plant characters under observation are given in Table 10. It will be noticed that the coefficients of correlation of yield of grain with days to tasseling and silking are negative in both years. Unpublished data at the Virginia Experiment Station indicate that corn plants which tassel and silk early mature late and yield high. Thus, a negative correlation is to be expected between yield per plant and the time at which corn plants tassel and silk. It has been commonly observed that, as a rule, the variety of corn that matures latest, other things being equal, will give the highest yield. This condition apparently holds for plants within a variety as shown by unpublished results at the Virginia Experiment Station.

The correlation of yield with average length of leaf and with average width of leaf is fair, being larger in the latter instance. There is a somewhat larger correlation of yield with number of nodes below the ear than that with number of nodes above the ear. This same condition is found in regard to the height of stalk below the ear and height above the ear. Such results indicate there is more relation between yield and the portion of the stalk below the ear than with that portion above the ear. The coefficients of correlation of yield of grain per stalk with weight of cob, weight of stalk, and circumference of stalk are high and significant.

The correlation coefficients of height of stalk below the ear with height of stalk above the ear vary rather widely. From these data it cannot be concluded whether any relation exists between the height of stalk below the ear and that above the ear.

It would be a distinct advantage if it were possible to select high yielding strains of corn by some character measurable before tasseling. It would eliminate much of the labor involved in the ear-to-row test and give opportunity of preventing pollination by undesirable strains. The character of circumference or size of stalk give promise of being important in this regard. It will be noticed that the correlation of weight of grain per stalk with circumference of stalk is $.653 \pm .020$ and the highest secured between any of the plant characters. Ewing (1910) found a correlation coefficient of $.393 \pm .020$ between weight of grain and diameter of stalk. Montgomery (1911) correlated a number of plant characters with yield, but did not use size of stalk. He considered that none of the characters studied were of much importance in indicating yield possibilities.

Linearity of Regression.—Regression is said to be linear when the means of the plotted arrays are best fitted by a straight line. If the regression is linear, the

constants $\eta-r$, η^2-r^2 , and Σ_m are equal to zero within the limits of the probable errors. The correlation ratio, η , as calculated from the formula $\eta = \frac{\sigma_{my}}{\sigma_y}$ where σ_{my} is the standard deviation of the weighted means of the y arrays about the mean of the population. Σ_m , the square root of the mean square deviation of the means of the arrays from the regression line, was calculated from the formula, $\Sigma_m = \sigma_y \sqrt{\eta^2 - r^2}$ (Pearson, 1905). The probable errors of $\eta-r$ and η^2-r^2 were calculated by the method of Blakeman (1905).

The above constants have been calculated for some of the characters under observation and are presented in Table 13. From a study of Table 13 it will be seen, that the differences between $\eta-r$ and η^2-r^2 are more than three times the probable error in instances of weight of grain with length of ear and percentage of grain with average length of kernel of the low yielding strains; and weight of grain with percentage of grain of the low yielding strains and the random sample. In the other instances studied the differences in these constants are less than three times the probable errors. In all instances where $\eta-r$ and η^2-r^2 are markedly greater than zero, Σ_m also shows a sensible deviation. Where the correlation ratio minus the correlation coefficient and Σ_m do not differ sensibly from zero it may be assumed that the best fitting straight line will give as good results as any other curve.

The regression lines of the various characters shown in Table 13 have been calculated and plotted with the means of the arrays. In calculating the regression lines and the equations to the lines the method as given by Yule (1897, 1919) and Elderton (1906) has been used.

The regression equations with their standard errors are given below. The relation of the correlation ratios and correlation coefficients of weight of grain with length of ear, weight of grain with percentage of grain, percentage of grain with average length of kernel of the low yielding strains; and weight of grain with percentage of grain of the random sample indicates a sensible departure from linearity. In view of this fact the equations for these characters would be less reliable than those of the other characters for which the equations have been calculated. The regression equations are also given for yield of grain per stalk with average width of leaf in 1918 and in 1919, and yield of grain per stalk with circumference of stalk. The correlation ratios were not calculated for these three pairs of characters.

It will be seen from figures 2-19 that in many instances the fit of the middle portion of the curves is very good while that at the ends is poor. In some of these instances a comparison of the correlation ratio and correlation coefficient indicates linear regression. This discrepancy is due to the fact that both the correlation ratio and coefficient are calculated from the ordinates weighted with their frequency. Toward the middle where the frequencies are often comparatively large a good fit would be expected under such conditions, while toward the end, where the frequencies are comparatively small, some deviation is to be expected.

The goodness with which the regression lines fit the data can be told by observation and calculation of the percentage of individuals which are fitted by the lines. A further test of the goodness of fit can be calculated from the standard error. The standard error is secured by the formula $\Sigma = \sigma \sqrt{1-r^2}$. The value is given with each equation. It is obvious that the regression line might fit the plotted means closely, but if the standard deviations of the characters are large the standard error will be correspondingly large.

Table 13.—Analytical constants for linearity of regression.

Correlated characters		r	η	$\eta \cdot r$	Σm	$\eta^2 \cdot r^2$
High yielding strains:						
Weight of grain with length of ear.....		.873 $\pm$.006	.883 $\pm$.006	.009 $\pm$.004	.126 σ	.016 $\pm$.006
Weight of grain with average circumference of ear.....		.779 $\pm$.010	.779 $\pm$.010	.004 $\pm$.003	.079 σ	.006 $\pm$.004
Percentage of grain with tip value		.175 $\pm$.025	.206 $\pm$.024	.031 $\pm$.014	.109 σ	.012 $\pm$.005
Percentage of grain with butt value		.251 $\pm$.024	.261 $\pm$.024	.010 $\pm$.007	.072 σ	.005 $\pm$.004
Low yielding strains:						
Weight of grain with length of ear.....		.878 $\pm$.006	.894 $\pm$.005	.016 $\pm$.005	.168 σ	.028 $\pm$.009
Weight of grain with average circumference of ear.....		.794 $\pm$.009	.802 $\pm$.009	.008 $\pm$.004	.113 σ	.013 $\pm$.006
Percentage of grain with percentage of grain		.309 $\pm$.023	.375 $\pm$.022	.066 $\pm$.015	.212 σ	.045 $\pm$.011
Percentage of grain with tip value		.122 $\pm$.025	.147 $\pm$.025	.025 $\pm$.015	.082 σ	.007 $\pm$.004
Percentage of grain with butt value		.215 $\pm$.025	.241 $\pm$.024	.026 $\pm$.012	.109 σ	.012 $\pm$.005
Percentage of grain with average length of kernel.....		.485 $\pm$.020	.537 $\pm$.018	.052 $\pm$.011	.231 σ	.053 $\pm$.011
Random sample:						
Weight of grain with length of ear.....		.877 $\pm$.008	.898 $\pm$.007	.021 $\pm$.008	.193 σ	.037 $\pm$.014
Weight of grain with average circumference of ear.....		.793 $\pm$.014	.802 $\pm$.013	.009 $\pm$.006	.120 σ	.014 $\pm$.009
Percentage of grain with percentage of grain		.353 $\pm$.032	.448 $\pm$.029	.095 $\pm$.024	.276 σ	.076 $\pm$.019
Percentage of grain with tip value		.174 $\pm$.035	.205 $\pm$.035	.031 $\pm$.020	.108 σ	.012 $\pm$.008
Percentage of grain with butt value		.246 $\pm$.034	.285 $\pm$.034	.039 $\pm$.019	.144 σ	.021 $\pm$.010

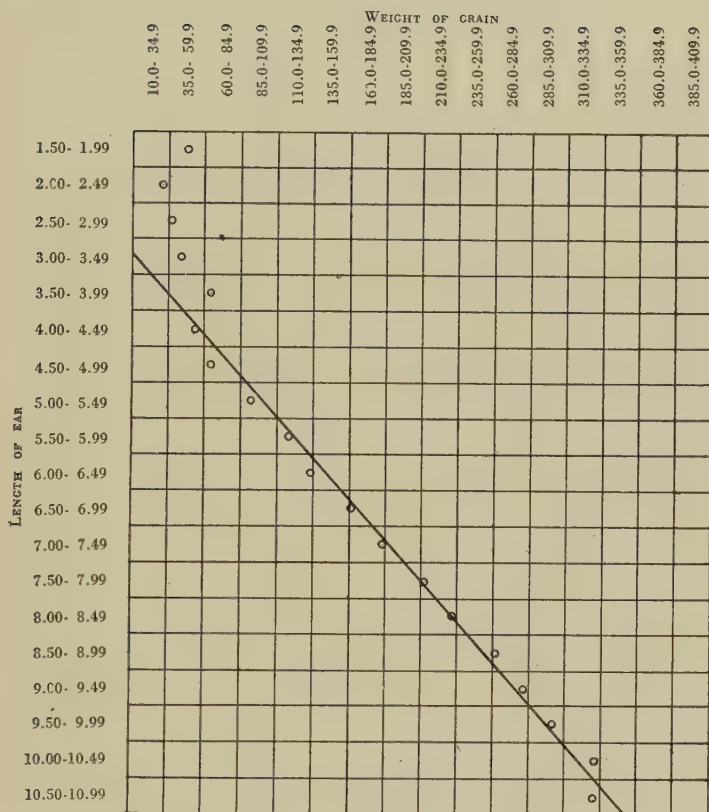


Figure 2.—Regression for weight of grain in grams and length of ear in inches of high yielding strains.

In figure 2 is shown the regression for weight of grain and length of ear of the high yielding strains. With exception of some of the end classes the regression line fits the plotted means fairly well. Both $\eta-r$ and η^2-r^2 are less than three times the probable errors, but Σ_m is equal to $.126\sigma$. Regression for weight of grain and length of ear of the low yielding strains is non-linear as shown by observation of figure 3

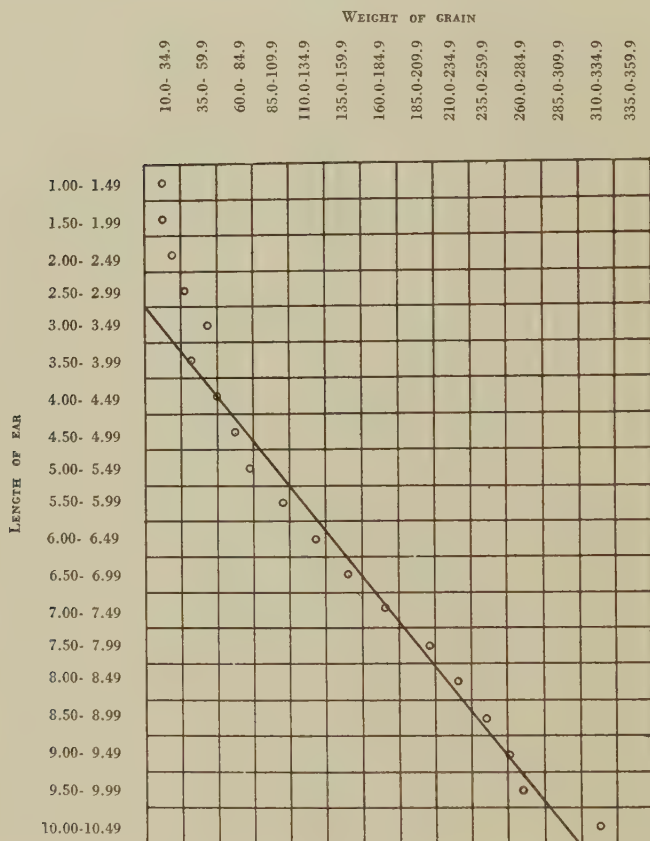


Figure 3.—Regression for weight of grain in grams and length of ear in inches of low yielding strains.

and by the difference between the correlation ratio and correlation coefficient. The regression for weight of grain and length of ear of the random sample as given in figure 4 is apparently non-linear. However, the difference between the correlation

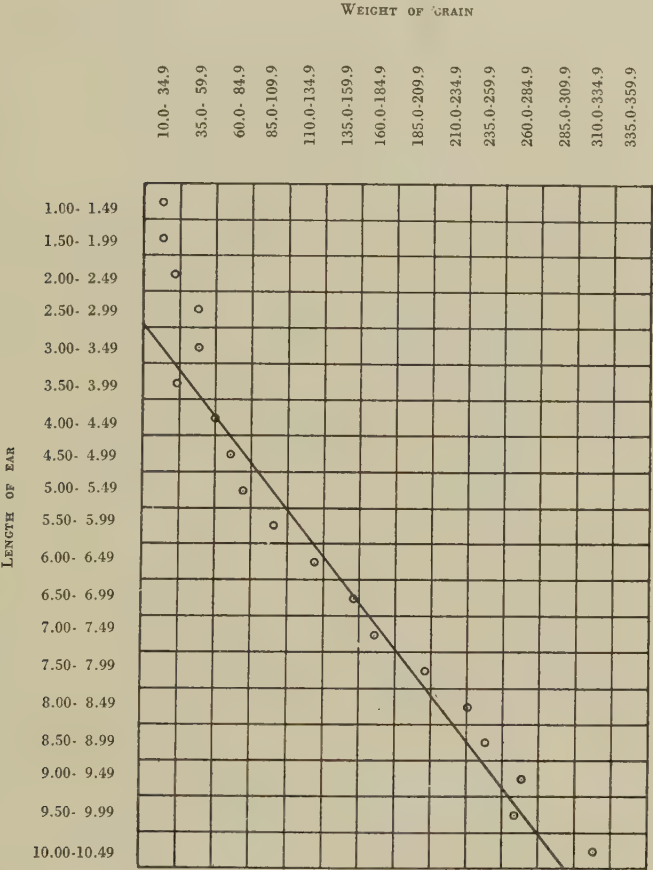


Figure 4.—Regression for weight of grain in grams and length of ear in inches of random sample.

ratio and correlation coefficient indicates linearity, while Σ_m is $.193\sigma$, a rather wide departure from zero.

The regressions for weight of grain and average circumference of ear of the high yielding strains, low yielding strains, and random sample are given in figures 5, 6, and 7. The regression straight lines fit the data satisfactorily with exception of the ends.

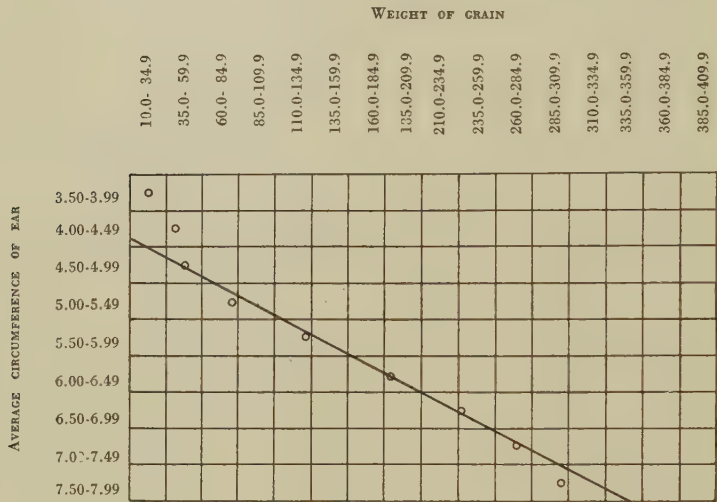


Figure 5.—Regression for weight of grain in grams and average circumference of ear in inches of high yielding strains.

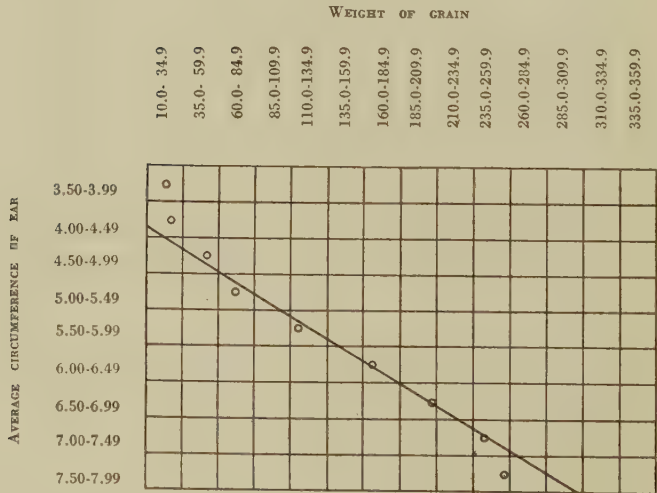


Figure 6.—Regression for weight of grain in grams and average circumference of ear in inches of low yielding strains.

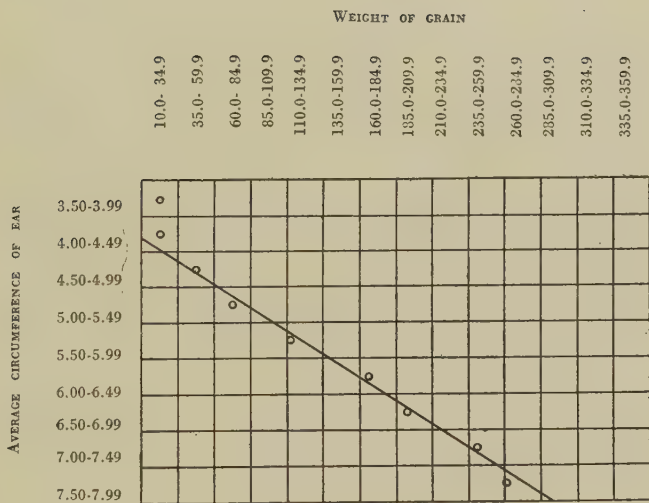


Figure 7.—Regression for weight of grain in grams and average circumference of ear in inches of random sample.

It is evident from observation of figures 8 and 9 that the regression for weight of grain and percentage of grain of the low yielding strains and random sample, respectively, is not linear. This denotes parabolic regression. Therefore, a curve of

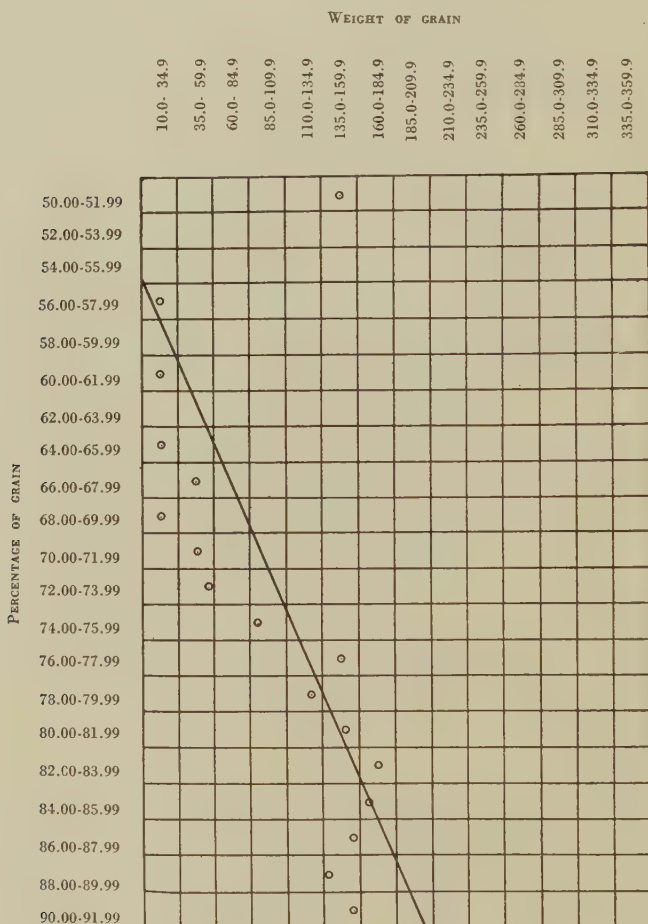


Figure 8.—Regression for weight of grain in grams and percentage of grain in inches of low yielding strains.

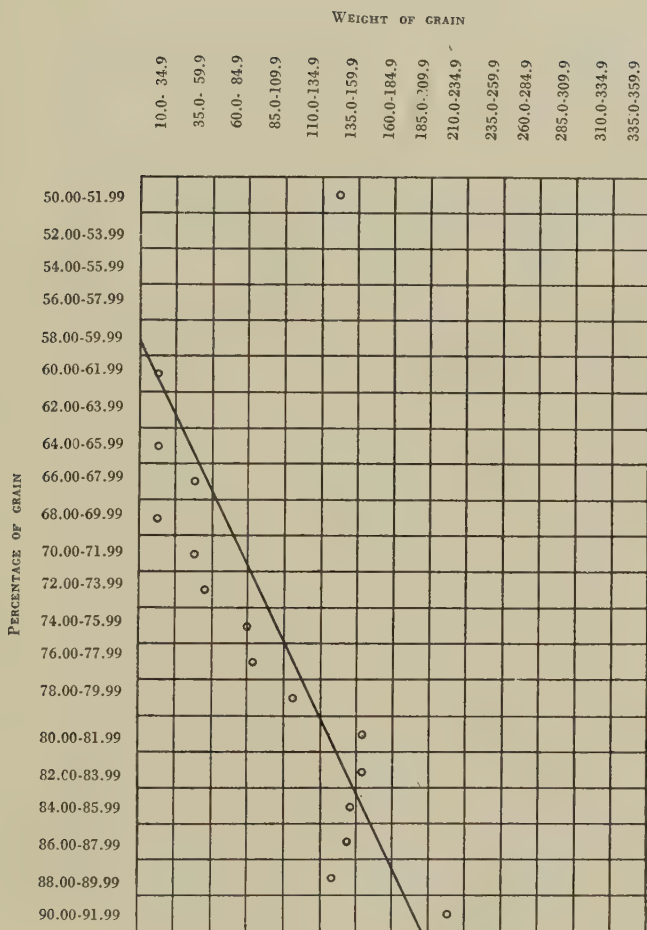


Figure 9.—Regression for weight of grain in grams and percentage of grain in inches of random sample.

some parabolic order should be used in these instances. It will be noted from Table 13 that in both instances $\eta-r$ and η^2-r^2 and Σ_m depart sensibly from zero.

As shown in figure 10 the regression straight line for percentage of grain and

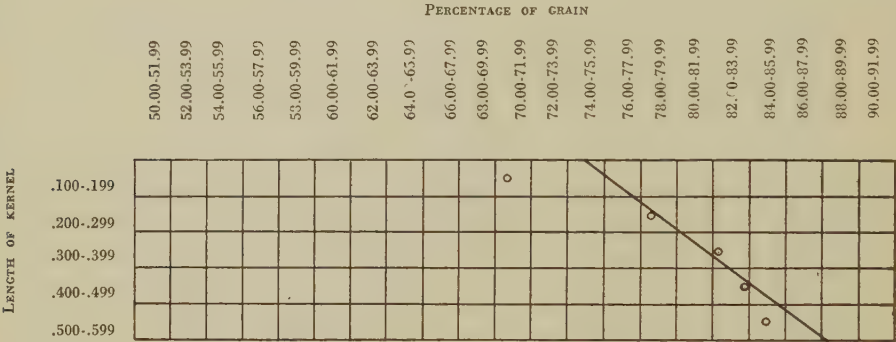


Figure 10.—Regression for percentage of grain and length of kernel in inches of low yielding strains.

length of kernel of the low yielding strains fits the plotted means fairly well. However, the value for $\eta-r$ and η^2-r^2 and Σ_m are significantly greater than zero.

Regression for percentage of grain and tip value of the high yielding strains is shown in figure 11. The fit of the regression line to the plotted means is fair. The

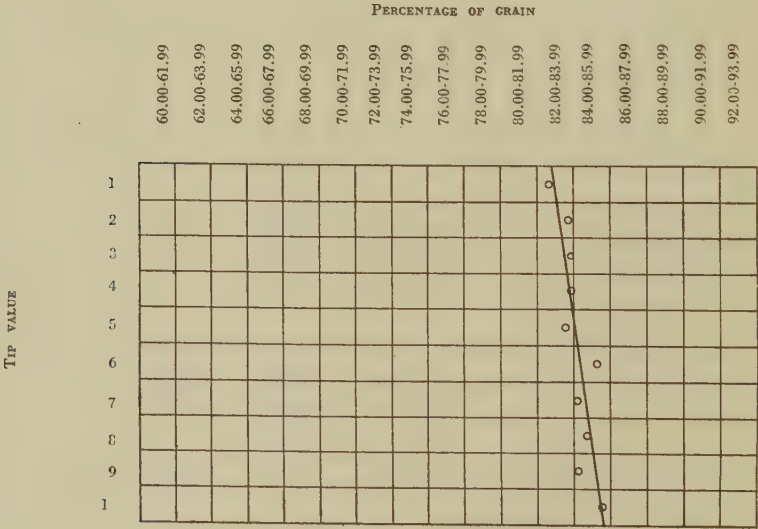


Figure 11.—Regression for percentage of grain and tip value of high yielding strains.

differences between $\eta-r$ and η^2-r^2 are not significantly great, but Σ_m is $.109\sigma$. As shown by the values of $\eta-r$, η^2-r^2 and Σ_m the fit of the regression straight line for percentage of grain and tip value of the low yielding strains is good. The results are plotted in figure 12. In case of regression for percentage of grain and tip value of

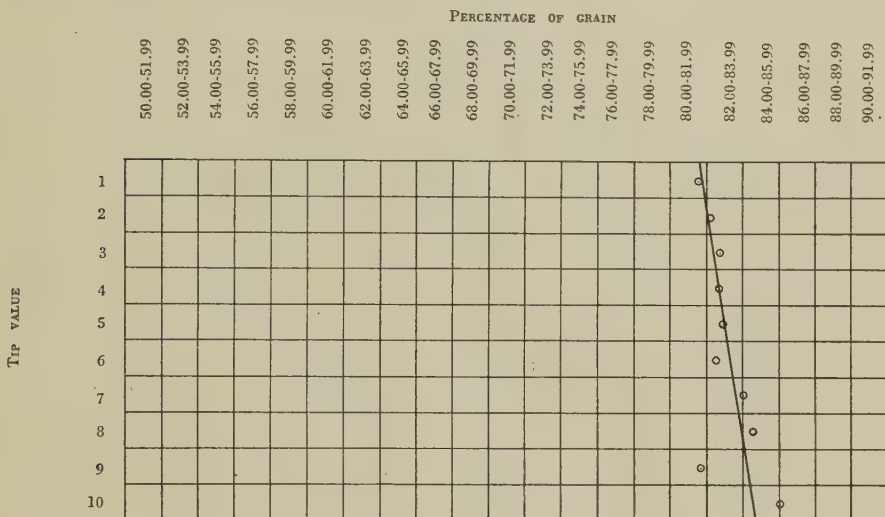


Figure 12.—Regression for percentage of grain and tip value of low yielding strains.

the random sample, figure 13, the fit is fair. Although the differences between $\eta-r$

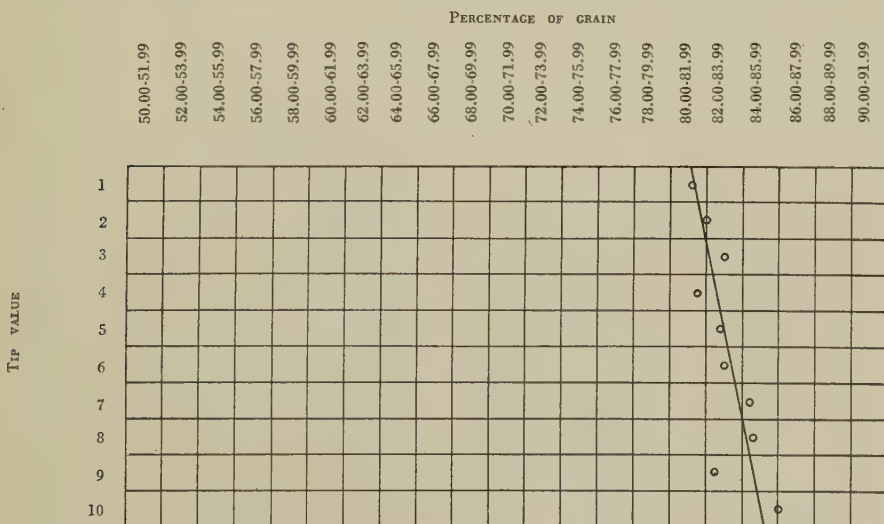


Figure 13.—Regression for percentage of grain and tip value of random sample.

$\eta^2 - r^2$ is within the limits of the probable errors, the value of Σ_m is $.108\sigma$.

The regression for percentage of grain and butt value of the high yielding strains, figure 14, is apparently linear. This agrees with the value as given in Table

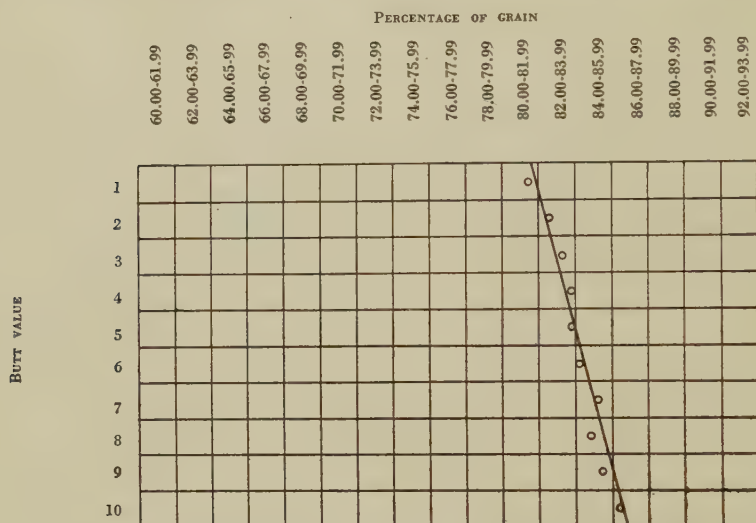


Figure 14.—Regression for percentage of grain and butt value of high yielding strains.

13. The fit of the regression straight line to the plotted means seem to be linear for the percentage of grain and butt value in case of the low yielding strains, figure 15. The differences between $\eta - r$ and $\eta^2 - r^2$ are not significant in comparison with

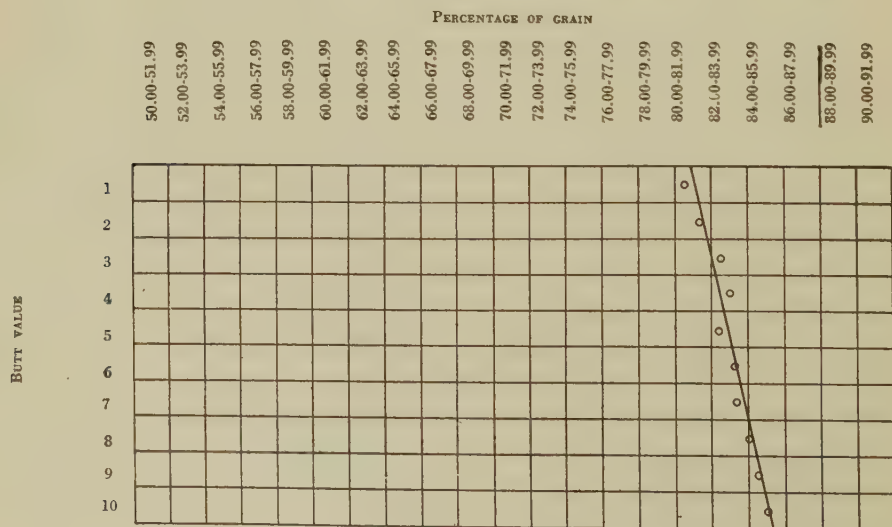


Figure 15.—Regression for percentage of grain and butt value of low yielding strains.

the probable errors, but Σ_m is equal to $.109\sigma$ which is a rather high value. Apparently from figure 16 the regression for percentage of grain and butt value of the

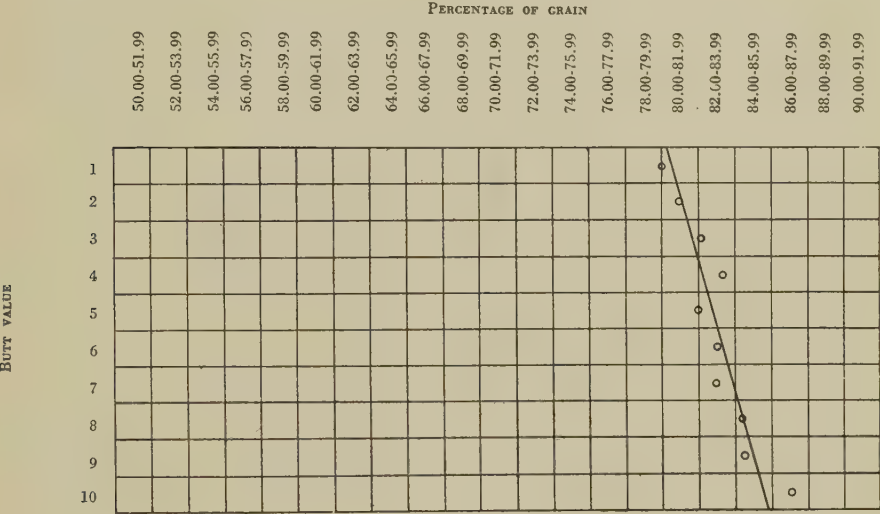


Figure 16.—Regression for percentage of grain and butt value of random sample.

random sample is not linear, as $\eta-r$ and η^2-r^2 would indicate. However, Σ_m has a value of $.144\sigma$ denoting a condition of non-linearity. Probably some curve other than the straight line will fit the data more satisfactorily.

The fit of the regression straight line to the plotted means is good for weight of grain and average width of leaf for 1918 and for 1919 as shown in figures 17 and 18.

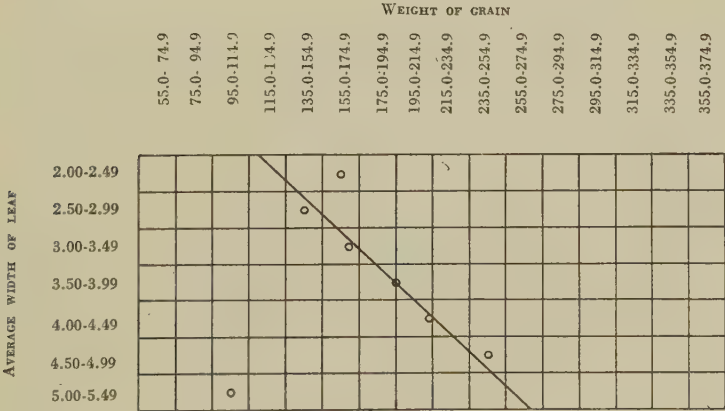


Figure 17.—Regression for weight of grain in grams and average width of leaf in inches for 1918.

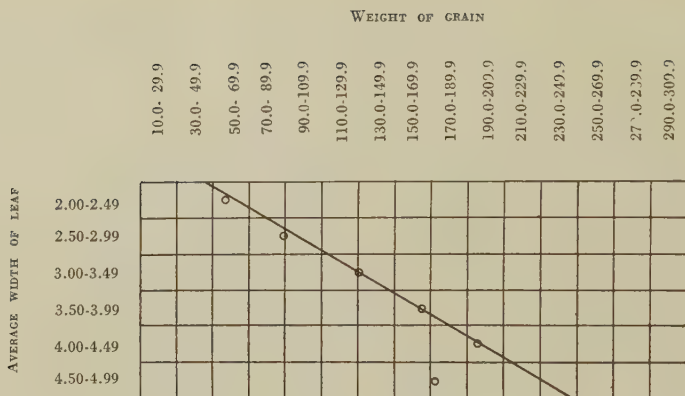


Figure 18.—Regression for weight of grain in grams and average width of leaf in inches for 1919.

There is apparently a linear regression for weight of grain and circumference of stalk for 1919 as shown in figure 19.

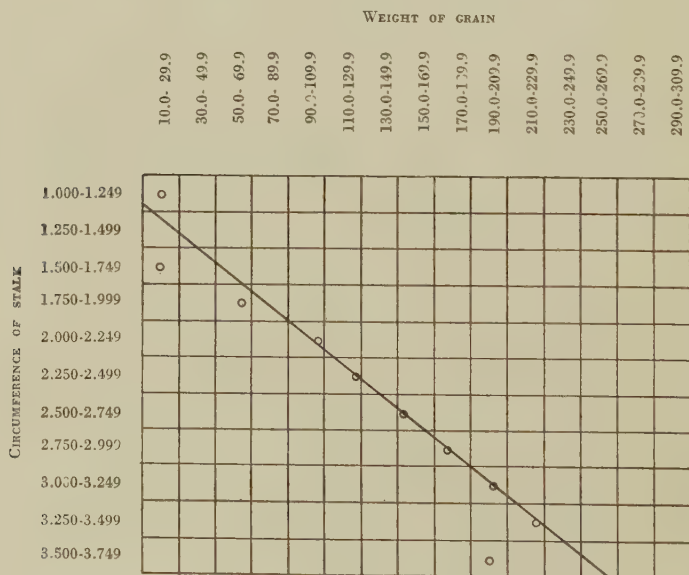


Figure 19.—Regression for weight of grain in grams and circumference of stalk in inches for 1919.

It has been brought out in the discussion of the linearity of the regression that in some cases non-linearity existed. In such cases the correlation ratio would be expected to give a better measure of the correlation of the characters involved than

the correlation coefficient. The data in such instances would be better fitted by some form of parabola than by the straight line curve.

The equations of the regression lines are as follows:

HIGH YIELDING STRAINS

Weight of grain.....=44.156	length	-131.697	Σ =39.418
Weight of grain.....=93.434	circumference	-398.199	Σ =51.050
Percentage of grain= .279	tip	+ 82.671	Σ = 3.597
Percentage of grain= .493	butt	+ 81.490	Σ = 3.539

LOW YIELDING STRAINS

Weight of grain.....=39.887	length	-111.448	Σ =33.446
Weight of grain.....=80.818	circumference	-343.207	Σ =42.454
Weight of grain.....= 5.288	percentage of grain.....	-282.565	Σ =66.403
Percentage of grain= .284	tip	+ 81.578	Σ = 4.047
Percentage of grain= .436	butt	+ 80.677	Σ = 3.986
Percentage of grain=26.740	length of kernel	+ 72.226	Σ = 3.566

RANDOM SAMPLE

Weight of grain.....=39.351	length	-109.165	Σ =34.008
Weight of grain.....=77.282	circumference	-324.563	Σ =43.148
Weight of grain.....= 5.918	percentage of grain	-339.483	Σ =66.316
Percentage of grain= .427	tip	+ 80.918	Σ = 4.460
Percentage of grain= .551	butt	+ 79.975	Σ = 4.388

1918

Yield of grain.....=42.322	width of leaf	+ 34.316	Σ =41.924
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1919

Yield of grain.....=66.980	width of leaf	- 88.939	Σ =41.980
Yield of grain.....=99.909	circumference of stalk.....	-110.165	Σ =39.379

Analytical Constants of Variation.—In the mathematical analysis of the different curves the methods of Pearson (1895; 1901) have been used. The curve types and some of the constants of variation were calculated for all the characters under observation and these are presented in Tables 14 and 15. Except where stated in the

Table 14.—Analytical constants of variation in ear characters under observation.

Constants	Length of ear				Tip value			
	High yielding strains	Low yielding strains	Random sample	Marketable ears	High yielding strains	Low yielding strains	Random sample	Marketable ears
μ_2	10.1268	9.3699	9.8930	2.8528	5.2430	2.9871	3.1060	3.6536
μ_3	-22.8618	-13.7147	-12.6216	1.7951	19.8805	10.9241	12.3646	10.3467
μ_4	349.9311	273.8729	306.2127	22.3747	139.8491	67.4029	76.3425	69.7907
σ_1	5.033	.2286	.1645	2.7423	2.7423	4.4773	5.1021	2.1950
β_1	3.4122	3.1194	3.1287	2.7492	5.0374	7.5540	7.9133	5.2282
Modal divergence	-17178	-42885	-3456	.2993	922.2630	10.1257	472.8483	2.9341
Standard deviation	1.597	1.537	1.579	.844	2.290	1.752	1.786	1.911
Skewness	-4495	-2788	-2189	.2717	402.7371	5.7795	264.7527	1.5354
Pearson's type of curve	I*	I*	I*	I	J	J*	J*	J
Constants	Average circumference of ear				Ratio butt circumference to tip circumference			
	High yielding strains	Low yielding strains	Random sample	Marketable ears	High yielding strains	Low yielding strains	Random sample	Marketable ears
μ_2	1.7992	1.8026	2.0315	1.0343	.8392	1.0218	1.0132	.5098
μ_3	-1.5518	-5126	-5236	.3467	.1062	-.4247	-.9942	-.1898
μ_4	11.1461	10.4301	12.7266	3.1235	5.9032	9.8119	8.2896	1.9506
σ_1	4135	.0449	.0327	.1086	-.0191	.1690	.5803	.2719
β_1	3.4433	3.2252	3.0838	2.9198	8.3828	9.3968	8.0751	7.5042
β_2	-2422	-.0645	-.0630	1.003	-.0011	-.0035	-.0106	-.0036
Modal divergence	.670	.686	.727	.508	.048	.052	.052	.038
Standard deviation	.3616	-.0941	-.0867	.1974	.0229	-.0670	-.2035	-.0957
Skewness	I	IV*	N*; IV*; V*	I	Heterotypic*	Heterotypic*	Heterotypic*	Heterotypic*
Pearson's type of curve								
Constants	Average circumference of cob				Percentage of grain			
	High yielding strains	Low yielding strains	Random sample	Marketable ears	High yielding strains	Low ¹ yielding strains	Random ¹ sample	Marketable ears
μ_2	.6012	.7289	.7745	.4832	3.2574	1.0375	1.1235	1.6605
μ_3	-.0398	.0350	.0896	.1857	-.8.1185	-.2.9001	-.2.5053	-.5384
μ_4	1.0475	1.7062	1.9529	.8131	80.0466	14.4178	15.6584	9.8147
σ_1	.0073	.0032	.0173	.2149	1.9070	4.7364	4.4255	.0633
β_1	2.8903	3.2110	3.2555	3.4827	7.5440	13.3952	12.4044	3.5597
β_2	-.0179	.0106	.0252	.0733	-.2.4598	-.2.5209	-.2.5954	-.2527
Modal divergence	.413	.450	.463	.376	3.656	4.080	4.226	2.576
Standard deviation	-.0434	.0236	-.0545	.1949	1V*	-.6029	-.6142	-.0981
Skewness	N*; I*	IV*	IV*	IV*	IV*	VI*	VI*	IV*
Pearson's type of curve								

Table 14 (Continued).—Analytical constants of variation in ear characters under observation.

Constants	Butt value			
	High yielding strains	Low yielding strains	Random ¹ sample	Marketable ears
μ_2	3.3880	3.9578	.9062	3.0622
μ_3	1.7745	5.2621	.4390	2.3332
μ_4	33.5202	44.3682	1.6209	26.3261
β_1	.0810	.4467	.2589	.1896
β_2	2.9202	2.8325	1.9738	2.8074
Modal divergence	.3191	1.5618	—3.5203	.5673
Standard deviation	1.863	2.010	1.972	1.774
Skewness	.1713	.7770	—1.7851	.3198
Pearson's type of curve	I*	I*	J	I*
Constants	Length of kernel			
	High yielding strains	Low yielding strains	Random sample	Marketable ears
μ_2	.4134	.5482	.5562	.3802
μ_3	— .2063	— .1170	— .1088	— .0092
μ_4	.7159	1.0078	1.0191	.4714
β_1	.6025	.0831	.0688	.0015
β_2	4.1883	3.3540	3.2943	3.2616
Modal divergence	— .0215	— .0093	— .0087	— .0010
Standard deviation	.070	.074	.075	.062
Skewness	— .3077	— .1260	— .1163	— .0167
Pearson's type of curve	V*; IV*	IV	IV	IV
Constants	Number of rows			
	High yielding strains	Low yielding strains	Random sample	Marketable ears
μ_2	1.9239	1.8656	1.8775	1.2673
μ_3	.9426	.0016	— .1652	.6162
μ_4	15.3706	11.8555	10.8932	5.4873
β_1	.1248	.000005	.0041	.1866
β_2	4.1527	3.4063	3.0904	3.4166
Modal divergence	.3181	.0007	— .0834	.4481
Standard deviation	2.794	2.732	2.740	2.324
Skewness	.1139	.0003	— .0304	.1928
Pearson's type of curve	IV	IV	N	IV*; V*

Table 14 (Continued).—Analytical constants of variation in ear characters under observation.

Constants	Weight of grain			
	High yielding strains	Low yielding strains	Random sample	Marketable ears
μ_2	10.3545	7.7176	7.9503	3.1491
μ_3	—4.3799	3.3866	6.7956	—2.4190
μ_4	250.9672	138.5339	163.2776	27.2177
β_1	.0173	.0250	.0919	.1874
β_2	2.3408	2.3259	2.5832	2.7446
Modal divergence	—10.8603	11.7810	17.7297	15.3270
Standard deviation	80.775	69.825	70.850	44.950
Skewness	— .1344	.1687	.2502	.3410
Pearson's type of curve	I*	I*	I*	I*

*Sheppard's corrections were used.

1. The classes were doubled before calculating the analytical constants.

2. N refers to normal curve.

Table 15.—Analytical constants of variation in plant characters under observation.

Constants	Number days to silking		Number days to tasseling		Average length of leaf		Average width of leaf		Number nodes below ear		Number nodes above ear	
	1913	1919	1918	1919	1918	1919	1918	1919	1918	1919	1918	1919
μ_1	3.5412	4.0829	4.8871	3.1923	1.6548	1.4883	.8032	.7620	.9231	1.1232	.4251	.5755
μ_2	3.1521	5.2112	3.9426	1.9995	.0497	-1.070	-.0060	-.2075	.6248	-.0102	.1311	.1470
μ_3	43.7515	66.7039	68.4148	38.4506	8.99.0	7.4228	1.9859	1.8229	3.0825	3.5025	.6479	1.4208
β_1	.2237	.3990	1.1332	.0005	.0005	.0025	.0.01	.0973	.4964	.0001	.2239	.1134
β_2	3.8876	4.0014	2.8645	3.7730	3.2830	3.3513	3.0779	3.1391	3.6178	2.7763	3.5853	4.2899
Modal divergence	.6740	1.0375	1.0439	.0955	.0955	-.0590	-.0018	-.0684	.3666	-.0054	.1339	.0791
Standard deviation	3.764	4.062	4.4430	3.574	2.572	2.506	.443	.459	1.003	1.059	.713	.759
Skewness	.1791	.2542	.2546	.1300	.0099	-.0236	-.0040	-.1439	.3655	-.0051	.1879	.1043
Pearson's type of curve	IV	IV*	I*	IV	IV	IV*	N	III*, V*, VI*	I*	I	IV*; V*	IV
Constants	Height of stalk below ear		Height of stalk above ear		Weight of cob		Weight of stalk		Circumference of stalk		Weight of grain per stalk	
	1918	1919	1918	1919	1918	1919	1918	1919	1918	1919	1918	1919
μ_1	.9533	.6401	1.1354	.9546		1.1094		3.3222		1.8470	5.2096	6.6823
μ_2	.6531	.2188	-.3660	-.2898		.7773		3.2873		-.6349	1.0848	-4.1641
μ_3	3.9402	1.4325	3.4517	3.4178		4.9803		39.2962		11.8604	22.3986	129.6329
β_1	.4627	.1826	.0915	.0965		.4426		.2947		.0640	.0083	.0581
β_2	4.3426	3.4964	2.6777	3.7510		4.0466		3.5605		3.4768	3.6624	2.9031
Modal divergence	1.9631	1.2029	-.8934	1.9066		2.8791		9.2284		-.0348	1.4978	7.1194
Standard deviation	7.698	6.400	8.520	7.704		10.920		36.900		.340	46.020	52.020
Skewness	.2580	.1880	-.1160	-.2238		.2636		.2501		-.1023	.0325	-.1369
Pearson's type of curve	IV	IV	I	IV		IV*		V*		IV	IV*	I*

*Sheppard's corrections were used.
I, N refers to normal curve.

paper the curve types were determined by calculating β_1 and β_2 and using the tables as given by Rhind (1909) and Pearson (1914). Wherever curves were fitted the goodness of fit was determined by calculating χ^2 and securing the corresponding P value from the tables given by Elderton (1901) and Pearson (1914). Skewness was calculated from the formula, skewness = $\frac{d}{\sigma}$, in which $d = \frac{\mu_3(\mu_4 + 3\mu_2)}{2(5\mu_2\mu_4 - 6\mu_3 - 9\mu_1)}$ as given by

Pearson (1902). The probable error of skewness was calculated by the formula, Pearson and Filon (1898), $P.E._{sk} = .6745 \sqrt{\frac{3}{2n}}$ or put in a simpler form, $P.E._{sk} =$

$1.7320508\chi_2$, where χ_2 is the function given by Miss Gibson (1906). The probable error of skewness for the high yielding strains is $\pm .0315$; the low yielding strains, $\pm .0317$; the random sample, $\pm .0449$; the marketable ears, $\pm .0473$; the plant characters for 1918, $\pm .0449$; for 1919, $\pm .0422$. Some of the curve types are marked with an asterisk, in such cases Sheppard's corrections were used. Where not so marked the raw moments were used in the calculations. All calculations were carried to six decimals in determining the constants in Tables 14 and 15. For some of the characters more than one curve type is given. It is probable in such cases that the data can be well fitted by more than one type of curve. It will be noted under the ratio of butt circumference to tip circumference that the curve types are marked heterotypic. Apparently the distributions are compound and will have to be resolved into their components before the curve types can be determined and fitted. Of the forty calculations made for curve types for ear characters, fourteen are type IV and are, therefore, of unlimited range in both directions and skew. Thirteen of the forty are of type I, therefore, being skew and having limited range in both directions. Of the twenty-one curve calculations made for the plant characters five are type I and thirteen type IV.

Curves have been fitted for seven distributions, figures 20 to 26. Of this number five are type I and two type IV. The equations to these curves are given below.

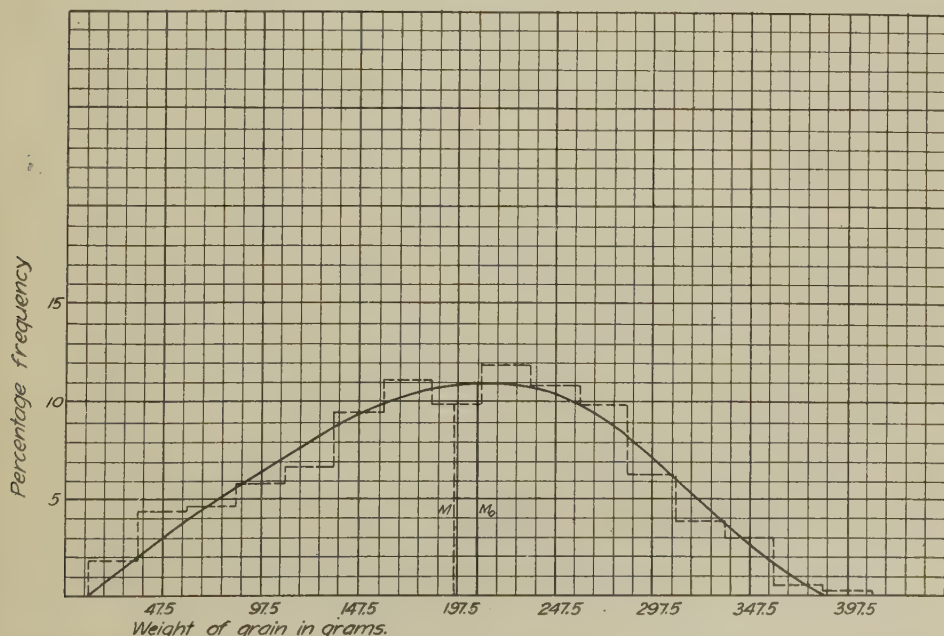


Fig.20.- Histogram and fitted curve for variation of grain in weight—high yielding strains.

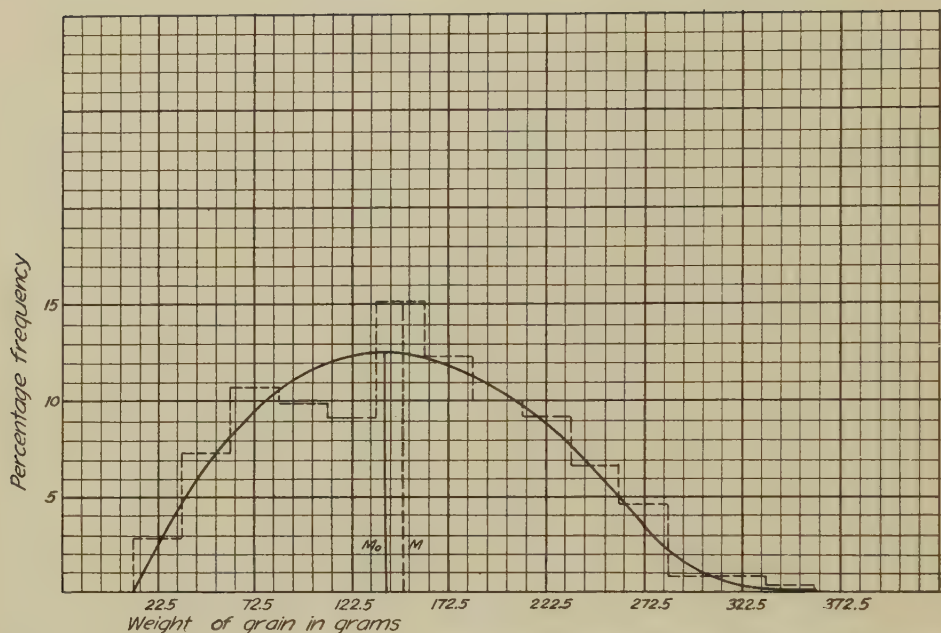


Fig.21.— Histogram and fitted curve for variation of grain in weight—low yielding strains

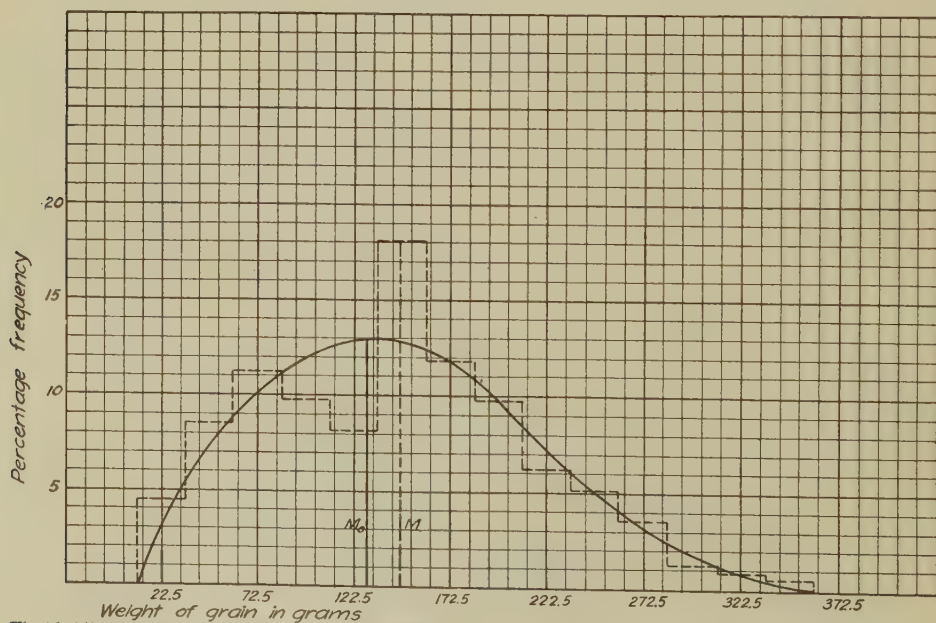


Fig.22.—Histogram and fitted curve for variation of grain in weight—random sample

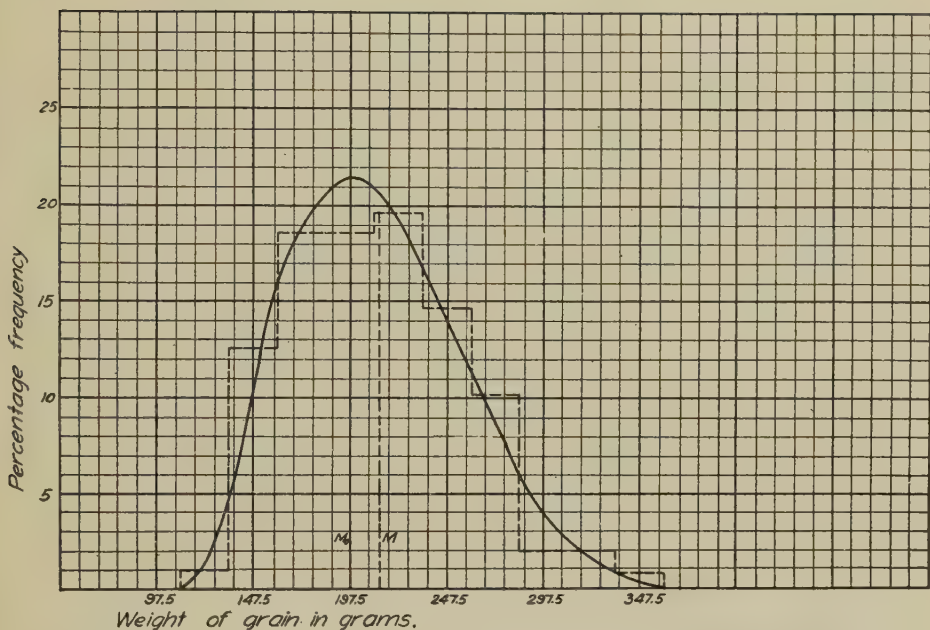


Fig.23-Histogram and fitted curve for variation of grain in weight-marketable ears.

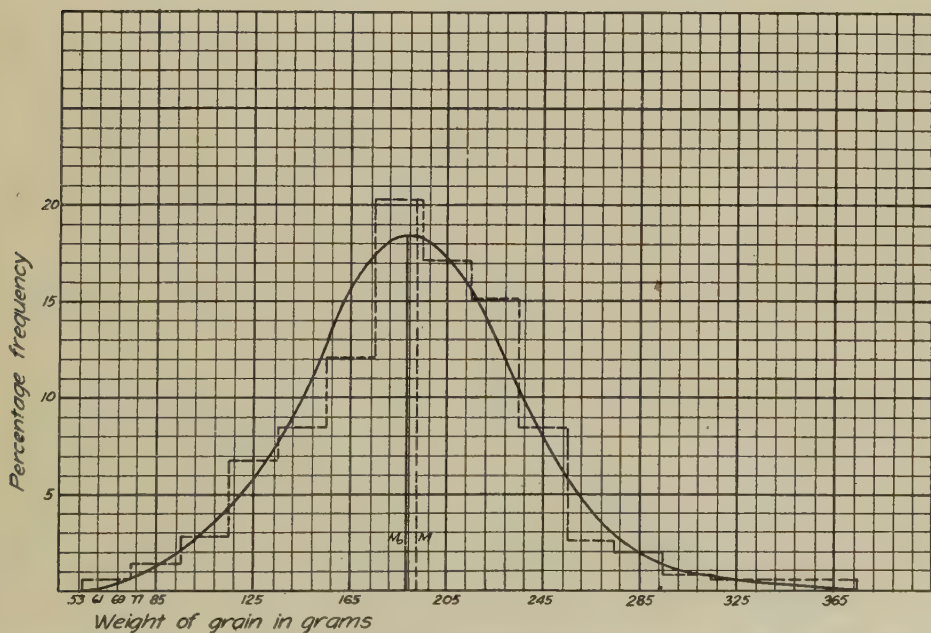


Fig.24-Histogram and fitted curve for variation of yield of grain per stalk - 1918

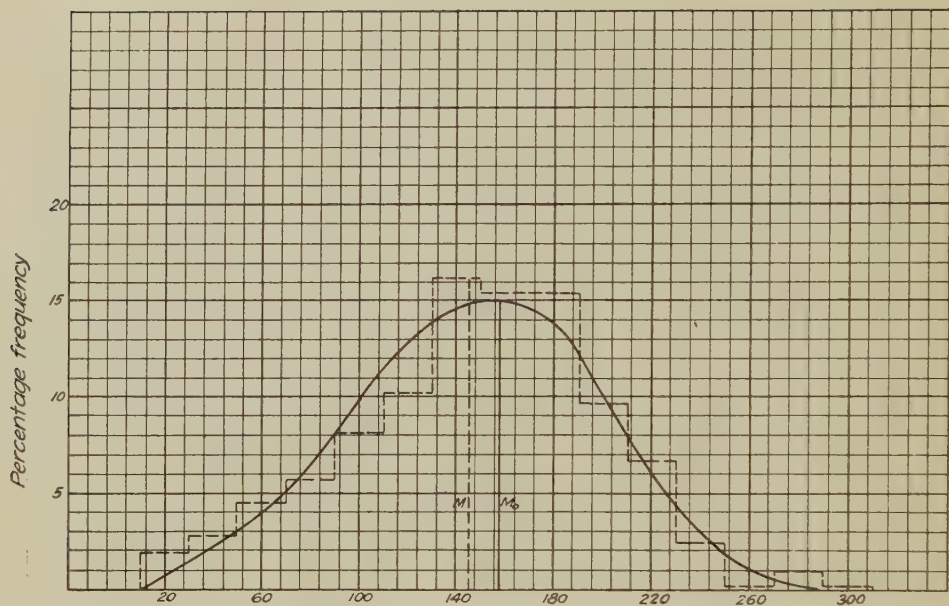


Fig.25.-Histogram and fitted curve for variation of yield of grain per stalk -1919

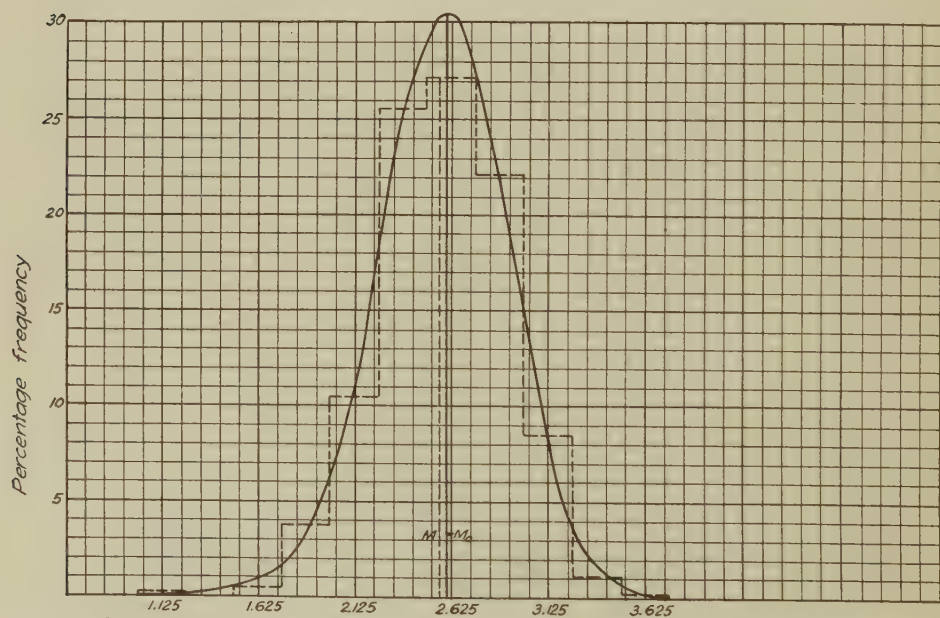


Fig.26.-Histogram and fitted curve for variation of stalk in circumference -1919

The equations to the fitted curves are as follows:

WEIGHT OF GRAIN

High yielding strains:

$$Y = 76.6249 \left(1 + \frac{X}{9.6346}\right)^{2.1804} \left(1 - \frac{X}{7.1721}\right)^{1.6147}$$

Low yielding strains:

$$Y = 86.2243 \left(1 + \frac{X}{5.8325}\right)^{1.4263} \left(1 - \frac{X}{8.4103}\right)^{2.0575}$$

Random sample:

$$Y = 44.6721 \left(1 + \frac{X}{5.8964}\right)^{2.0419} \left(1 - \frac{X}{11.6207}\right)^{4.0242}$$

Marketable ears:

$$Y = 65.6513 \left(1 + \frac{X}{3.2305}\right)^{1.8368} \left(1 - \frac{X}{8.5668}\right)^{4.8707}$$

1918:

$$Y = \frac{61.5191}{7.1253} e^{-(-.8559) \tan^{-1} \left(\frac{X}{7.6372}\right)} \left(1 + \frac{X}{7.6372}\right)^2$$

1919:

$$Y = 58.2398 \left(1 + \frac{X}{20.5972}\right)^{18.9585} \left(1 - \frac{X}{9.9025}\right)^{9.1147}$$

Circumference of stalk:

$$Y = \frac{65.6516}{10.5042} e^{-4.9829 \tan^{-1} \left(\frac{X}{5.5771}\right)} \left(1 + \frac{X}{5.5771}\right)^2$$

It will be noticed that the data for the weight of grain in 1918 and the circumference of stalk seems best fitted by type IV curves. It will be seen from Table 16 that the remaining five curves are of type I. The lower or (—) end of the range in four out of the five type I curves given negative values. The values of the upper or (+) end are by no means unreasonable. It will be noticed that the upper range of the curve of the high yielding strains is less than the upper limit of the highest observed class. The limits of the highest observed class is 385.0 to 409.9 grams, while the upper range of the curve is 386.7575 grams. There is one individual in this class and it weighs 399.5 grams. The curve, therefore, underestimates the weight at this end. The theoretical frequency of this class is negative as shown in figure 20. It

Table 16.—Analytical constants of variation for the fitted curves.

Constants	Weight of grain					Circumference of stalk
	High yielding strains	Low yielding strains	Random sample	Marketable ears	1918	1919
μ_2	10.3545	7.7176	7.9503	3.1491	5.2006	8.6823
μ_3	-4.3799	8.3866	6.7956	2.4190	1.0848	-4.1641
μ_4	250.9672	138.5339	163.2776	27.2177	99.3986	129.6329
β_1	.0173	.0250	.0919	1874	.0083	.0581
β_2	2.3408	2.3259	2.5832	2.7446	3.6624	.0640
β_3	-1.3703	-1.4232	-1.1093	-1.0730	1.2099	2.9031
K_2	-.0097	-.0135	-0.64	-1383	.0049	-.3681
Standard deviation	80.775	69.825	70.850	44.950	46.020	.0064
Modal divergence	-10.8603	11.7810	17.7297	15.3270	1.4978	.340
Skewness	-.1344	.1687	.2502	3410	.0325	-.0348
Mean	196.5950	152.1325	144.9125	210.8600	191.4897	-.1023
Mode	207.4550	140.3552	127.1825	195.5825	189.9919	2.5794
Type of curve	I*	I*	I*	I*	IV*	IV
+ end of curve	386.7575	350.6100	417.7000	409.7025	+ α	+ α
- end of curve	-34.6600	-5.6600	-20.2275	114.7701	- α	- α
Y_n	76.0249	86.2243	44.6721	65.6513	61.5191	65.6516

*Sheppard's corrections used.

might be stated that the ears producing this amount of grain are comparatively infrequent. In case of the low yielding strains the limits of the highest observed class is 335.0 to 359.9, while the upper range of the curve is 350.6100 grams. There are two individuals in this class one of which weighs 349.5 grams and the other 341.0 grams. In 1918 the limits of the highest class was 355.0 to 374.9 grams while the upper range of the curve is 352.6700 grams. It is obvious that the curve underestimates the weight at this end.

The greatest total range is that of the weight of grain for 1919 which is approximately 610 grams. This weight of grain per ear is not impossible of production but it is not very probable. The range of the random sample is 437.9 grams which is entirely possible. It is likely with larger numbers the tendency to over-estimation would be diminished. It will also be noticed that the curves approach rather closely to the normal type in some instances. The range of the latter is unlimited in both directions and as a limited range curve approaches the normal type its range tends to increase rather rapidly.

In case of the high yielding strains, low yielding strains, random sample, marketable ears, and for the weight of grain for 1919 the value for κ_2 is negative. Such a value of κ_2 indicates a type I curve. However, this value for the high yielding strains, low yielding strains, and random sample approaches zero rather closely. From this value and those from β_1 and β_2 it would seem that a type II curve might fit the data as well as a type I. The type II curve was fitted in all three instances, but the results were not as satisfactory as with the type I.

The histograms and fitted curves are shown in figures 20 to 26. All areas have been reduced to the percentage basis. The absolute and percentage frequencies are shown in Table 17.

The χ^2 and P values were determined for the curves fitted and are presented in Table 18. The χ^2 value for the high yielding strains is 11.168 with a corresponding P value of .7403. A value of this magnitude indicates that the data are well fitted by the curve type used.

The χ^2 value for the low yielding strains is 92.063 and the corresponding P value, which would be very small, is not given in Pearson's tables. The fit is not as poor, however, as would first appear. The 347.5 class makes up 72.975 and the 297.5 class 4.925 of the value. Therefore, over most of the curve the fit is fair.

The χ^2 value of the random sample is 19.968 which leads to a P value of .0961. The fit is not so poor as first indicated as classes 122.5 and 147.5 make up 13.284 of the χ^2 value. Thus, with exception of these two classes, the data are fitted well by the curve.

The marketable ears have a χ^2 value of 39.452 and a P value of .000032. Of the χ^2 value the last class and class 297.5 contributes 32.147 and 3.473, respectively. In other words, on the whole, the fit is very good.

In 1918 a χ^2 value of 12.744 was obtained with a P value of .6219. These results indicates that the curve type used fits the data well.

In 1919 the χ^2 value was 23.738 with a P value of .0496. It will be noticed that classes 20, 260, 280 and 300 contribute 17.775 to the χ^2 value. It follows that with exception of these classes the fit is very good.

In case of the circumference of the stalk the χ^2 value is 8.366 and P equals .5934. These values indicate a fair fit. However, one class, 1.125 contributes 3.619 to the χ^2 value. Therefore, with exception of this class the fit of the curve is excellent.

Although the fit of the curves in some instances is rather irregular, but considered

Table 17.—Frequency distributions of variations. Absolute and percentage frequencies.

Weight of grain, grams	High yielding strains			Low yielding strains			Random sample			Marketable ears			1918			1919			Circumference of stalk, inches	Totals	1919
	Absolute	Percentage	Frequency	Absolute	Percentage	Frequency	Absolute	Percentage	Frequency	Absolute	Percentage	Frequency	Absolute	Percentage	Frequency	Absolute	Percentage	Frequency			
10.0-34.9	12	1.74	20	2.94	15	4.44		55.0-74.9	2	.59	7	1.82	1	.26							
35.0-59.9	29	4.20	49	7.21	29	8.58		75.0-94.9	5	1.47	10	2.60	0	0							
60.0-84.9	32	4.64	73	10.74	38	11.24		95.0-114.9	10	2.95	17	4.43	2	.52							
85.0-109.9	41	5.94	67	9.85	33	9.76		115.0-134.9	23	6.78	22	5.73	14	3.65							
110.0-134.9	46	6.67	63	9.26	28	8.28	3	135.0-154.9	29	8.55	31	8.07	41	10.68							
135.0-159.9	65	9.42	103	15.15	61	18.05	39	155.0-174.9	41	12.09	40	10.42	2,000-2,249	27.34							
160.0-184.9	77	11.16	84	12.35	41	12.13	57	175.0-194.9	69	20.35	62	16.15	2,250-2,499	25.52							
185.0-209.9	68	9.86	68	10.00	33	9.76	57	195.0-214.9	59	17.40	59	15.36	2,500-2,749	86	22.40						
210.0-234.9	82	11.88	63	9.26	21	6.21	60	215.0-234.9	51	15.04	57	15.36	3,000-3,249	32	8.33						
235.0-259.9	75	10.87	45	6.62	17	5.03	44	235.0-254.9	29	8.55	37	9.64	3,250-3,499	4	1.04						
260.0-284.9	67	9.71	31	4.56	13	3.85	31	255.0-274.9	9	2.65	26	6.77	3,500-3,749	1	.26						
285.0-309.9	43	6.23	6	.88	4	1.18	6	275.0-294.9	7	2.06	9	2.34									
310.0-334.9	27	3.91	6	.88	3	.89	6	295.0-314.9	2	.59	26	6.77									
335.0-359.9	21	3.04	2	.29	2	.59	1	315.0-334.9	1	.29	3	.78									
360.0-384.9	4	.58					1	335.0-354.9	1	.29	1	.26									
385.0-409.9	1	.14					1	355.0-374.9	1	.29											
Totals	690	99.99	680	99.99	338	99.99	305	100.01	339	99.94	384	99.99	Totals	384	100.00						

Table 18.—Values for χ^2 and P for the fit of the theoretical curves to the observational curves for weight of grain and circumference of stalk.

	χ^2	P
<i>Weight of grain:</i>		
High yielding strains	11.168	.740235
Low yielding strains	92.063	*
Random sample	19.968	.096103
Marketable ears	39.452	.000032
Per stalk in 1918	12.744	.621941
Per stalk in 1919	23.738	.049607
Circumference of stalk in 1919	8.366	.593433

*Not given in Pearson's Tables.

as a whole the curves fit the data fairly well. In fact other curve types were fitted in some instances but the results were less satisfactory than those secured from the use of the curves reported in this paper.

SUMMARY

From the data presented in Part I the following results have been found:

In most cases the means of the ear characters of the high yielding strains are significantly greater than those of the low yielding strains. In no instances are there pronounced differences between the means of the low yielding strains and the random sample. In every instance, save one, the means of the characters of the marketable ears are greater than those of the low yielding strains.

The values of the means for the plant characters of 1918 are greater in every case, save two, than those of 1919.

As measured by the coefficient of variation the characters of the marketable ears are the least variable of the four samples of ear characters studied. There is a tendency for the low yielding strains to be more variable than the high yielding strains. In no instances are the differences in variation of the low yielding strains and random sample significant.

On the whole, the plant characters of 1919 are more variable than those of 1918.

The most variable ear characters are tip value, butt value, weight of grain, length of ear, and average length of kernel. The least variable character is percentage of grain.

The most variable plant characters are weight of cob, weight of grain, weight of stalk, height of stalk below the ear, and number of nodes below the ear. The least variable characters are days to silking and to tasseling.

Coefficients of correlation of weight of grain per ear with other characters are significantly positive in all instances, except ratio of butt circumference to tip circumference. In this latter case the results indicate either no relation or that weight of grain decreases with increase in cylindricity of the ear.

Percentage of grain increases as the length of kernel increases, but decreases as the diameter of the cob increases.

Correlations of yield of grain per stalk with days to tasseling and to silking indicate that the plants flowering late within a given variety produce less grain than the earlier flowering plants.

There is a marked correlation of yield of grain per stalk with weight of cob, weight of stalk, and circumference of stalk.

In most cases there are no marked differences between the coefficients of correlation of the high and low yielding strains. In no instance are the differences significant between the random sample and the low yielding strains. The correlations are in most cases higher for the low yielding strains than for the marketable ears.

The random sample used was representative of the entire sample as evidenced by lack of a marked difference for any constant when compared with the entire sample (low yielding strains). Such results indicate that a random sample will give as reliable conclusions as will the entire sample from which it is taken.

Apparently by the use of the score card alone high or low yielding strains of corn cannot be distinguished. But there are indications that the score card may be of value in selecting high yielding ears within strains.

The coefficients of correlation for the plant characters are higher in 1919 than in 1918.

In case of some of the pairs of characters correlated, the regression is non-linear. In such cases the correlation ratio is a better measure of the correlation existing than the coefficient of correlation.

The curve types for the characters under observation were determined. The data of the greatest number of the characters seem to be best fitted by curves of types I and IV. Curve types were fitted and P values calculated for the weight of grain for the four samples of the ear characters, the yield of grain per stalk for 1918 and 1919, and the circumference of stalk for 1919.

PART II

THE INHERITANCE OF CHARACTERS OF MAIZE AS INFLUENCED BY HYBRIDIZATION

The results of Part I of this investigation have shown that certain characters of the corn plant are closely correlated, while others show little, if any, correlation. In Part II of this investigation a study was made of the inheritance of various characters of the corn plant in the F_1 and F_2 hybrid generations and compared with the inheritance of the same characters of the parents. In addition coefficients of correlation were calculated for various characters in the P_1 , F_1 , and F_2 generations and compared with each other.

In the investigations two hybrids were used the parents of which differed more or less sharply in the characters to be studied. Crosses were made and the seed saved so that in 1921 the seed of the parents and the F_1 and F_2 hybrid generations were planted in such a way as to secure comparable data. The seed of the parents and the hybrids were planted in separate but adjoining rows and replanted four times. The rows were 32.6 inches apart and the plants were eighteen inches apart in the row. The various data needed were secured when the plants were in the proper stage of development for obtaining them.

The hybrids used were Alvor's Dent X Cornell No. 12, and Narrow leaf (pop corn) X Cornell No. 12.

Table 19.—Showing means, standard deviations and coefficients of variation.

Characters	Alvord's Dent	Cornell No. 12	Alvord's Dent and Cornell No. 12 (Aver- age)	Alvord's Dent X Cornell No. 12, F, Hybrid	Alvord's Dent X Cornell No. 12, F, Hybrid
	M	M	M	M	M
Number of nodes	12.066±.055	13.599±.074	12.843±.044	14.130±.074	11.700±.090
Circumference of stalk, inches.....	2.315±.013	2.554±.015	2.435±.010	2.602±.012	2.286±.019
Height of stalk, inches	75.570±.515	82.535±.511	79.053±.363	91.800±.509	74.665±.699
Days to pollen maturity	70.916±.191	73.852±.276	72.384±.157	75.256±.246	73.968±.378
Weight of stalk, grams	60.475±1.163	82.400±1.633	71.438±.947	116.525±2.520	46.950±1.708
Weight of grain, grams	105.650±2.039	162.325±3.464	133.988±1.757	191.375±3.595	74.175±2.640
Weight of cob, grams	21.610±.352	30.105±.553	25.858±.297	36.025±.587	19.500±.570
Average length of internodes, inches ..	6.237±.036	6.081±.039	6.159±.026	6.405±.039	6.395±.051
Characters	σ	σ	σ	σ	σ
Number of nodes	1.134±.039	1.316±.053	1.225±.031	1.523±.052	1.260±.063
Circumference of stalk, inches	.268±.009	.273±.011	.271±.007	.255±.009	.264±.013
Height of stalk, inches	10.725±.364	9.030±.361	9.878±.256	10.490±.360	9.835±.494
Days to pollen maturity	3.980±.135	4.884±.195	4.432±.111	5.064±.174	5.316±.267
Weight of stalk, grams	24.200±.822	28.850±1.155	26.525±.670	51.900±1.782	24.025±1.208
Weight of grain, grams	42.425±1.442	61.200±2.449	51.813±1.242	74.050±2.542	37.125±1.866
Weight of cob, grams	7.325±.249	9.765±.391	8.545±.210	12.090±.415	8.020±.403
Average length of internodes, inches ..	.757±.026	.692±.028	.725±.019	.797±.027	.716±.036
Characters	C	C	C	C	C
Number of nodes	9.38 ±.319	9.68 ±.387	9.53 ±.246	10.78 ±.374	10.77 ±.548
Circumference of stalk, inches	11.58 ±.399	10.69 ±.433	11.14 ±.293	9.80 ±.336	11.55 ±.588
Height of stalk, inches	14.19 ±.492	10.94 ±.443	12.57 ±.329	11.43 ±.397	13.17 ±.673
Days to pollen maturity	5.61 ±.191	6.61 ±.265	6.11 ±.155	6.73 ±.231	7.19 ±.361
Weight of stalk, grams	40.02 ±1.563	35.01 ±1.563	37.52 ±1.105	44.54 ±1.807	51.17 ±3.175
Weight of grain, grams	40.16 ±1.569	37.70 ±1.710	38.93 ±1.156	38.69 ±1.514	50.05 ±3.083
Weight of cob, grams	33.90 ±1.277	32.44 ±1.428	33.17 ±.951	33.56 ±1.275	41.13 ±2.392
Average length of internodes, inches ..	12.14 ±.419	11.38 ±.461	11.76 ±.310	12.44 ±.434	11.20 ±.570

Table 20.—Showing the coefficients of correlation between plant characters.

Days to pollen maturity, subject, correlated with	Alvord's Dent	Cornell No. 12	Alvord's Dent and Cornell No. 12 (Aver- age)	Alvord's Dent X Cornell No. 12, F, Hybrid	Alvord's Dent X Cornell No. 12, F, Hybrid
Number of nodes	.363±.042	.229±.054	.296±.033	.362±.042	.329±.063
Circumference of stalk, inches	.151±.047	-.209±.054	-.180±.035	-.135±.048	-.223±.068
Height of stalk, inches	-.209±.046	-.084±.056	.063±.036	.027±.049	.037±.071
Days to pollen maturity	.067±.048	-.096±.056	-.015±.036	-.440±.039	.074±.071
Weight of stalk, grams	.050±.048	-.242±.053	-.096±.036	-.182±.047	-.177±.069
Weight of grain, grams	-.003±.048	.183±.055	-.093±.036	-.150±.047	-.064±.071
Weight of cob, grams	-.037±.048	-.262±.053	-.150±.036	-.294±.044	-.243±.067
Average length of internodes, inches.....					
Weight of grain per stalk, subject, correlated with					
Number of nodes	.442±.039	.478±.044	.460±.029	.206±.046	.158±.069
Circumference of stalk, inches	.487±.037	.627±.034	.557±.025	.527±.035	.651±.041
Height of stalk, inches	.720±.023	.632±.034	.676±.019	.574±.033	.562±.049
Days to pollen maturity	.050±.048	-.242±.053	-.096±.036	-.182±.047	-.177±.069
Weight of stalk, grams	.691±.025	.678±.031	.685±.019	.556±.034	.585±.047
Weight of grain, grams					
Weight of cob, grams	.734±.022	.855±.015	.795±.012	.758±.021	.771±.029
Average length of internodes, inches.....	.517±.035	.218±.054	.368±.029	.360±.042	.522±.052

Table 21.—Showing comparison of the different means, standard deviations and coefficients of variation.

Characters	Alvord's Dent <i>minus</i> Cornell No. 12			Average of Alvord's Dent and Cornell No. 12			Alvord's Dent <i>minus</i>		
	F ₁ Hybrid		D/E	F ₂ Hybrid		D/E	F ₁ Hybrid		D/E
	Difference	M		Difference	M		Difference	M	
Number of nodes	-1.513 ± .092	16.446		-1.287 ± .086	14.965		-2.044 ± .092	22.217	
Circumference of stalk, inches	-2.239 ± .020	1.195		-1.67 ± .016	10.438		-.287 ± .018	15.944	
Height of stalk, inches	-6.965 ± .725	9.607		-12.747 ± .625	20.395		-16.230 ± .724	22.417	
Days to pollen maturity	-2.936 ± .336	8.738		-2.872 ± .292	9.836		-4.340 ± .311	13.955	
Weight of stalk, grams	-21.925 ± 2.005	10.935		-45.087 ± 2.692	16.749		-56.050 ± 2.775	20.198	
Weight of grain, grams	-56.675 ± 4.020	14.098		-57.387 ± 4.001	14.343		-35.725 ± 4.133	20.742	
Weight of cob, grams	-8.495 ± .656	12.950		-10.167 ± .658	15.451		-14.415 ± .684	21.075	
Average length of internodes, inches	.156 ± .053	2.943		-.246 ± .047	5.234		-.168 ± .053	3.170	
	σ			σ			σ		
Number of nodes	-1.182 ± .066	2.758		-.298 ± .061	4.885		-.389 ± .065	5.985	
Circumference of stalk, inches	-.005 ± .014	.036		-.016 ± .011	1.455		.013 ± .013	1.000	
Height of stalk, inches	1.695 ± .513	3.304		-.612 ± .442	1.385		.235 ± .512	.459	
Days to pollen maturity	-.904 ± .237	3.814		-.632 ± .206	3.068		-1.084 ± .220	4.927	
Weight of stalk, grams	-4.650 ± 1.418	3.279		-25.375 ± 1.904	13.327		-27.700 ± 1.962	14.118	
Weight of grain, grams	-18.775 ± 2.842	6.606		-22.237 ± 2.829	7.860		31.625 ± 2.923	10.819	
Weight of cob, grams	-2.440 ± .464	5.259		-3.545 ± .465	7.624		-4.765 ± .484	9.845	
Average length of internodes, inches	.065 ± .038	1.711		-.072 ± .033	2.182		-.040 ± .037	1.081	
	C			C			C		
Number of nodes	-30 ± 502	.598		-1.25 ± .448	2.790		-1.40 ± .492	2.846	
Circumference of stalk, inches	.89 ± .589	1.511		1.34 ± .446	3.004		1.78 ± .522	3.410	
Height of stalk, inches	3.25 ± .662	4.969		1.14 ± .516	2.209		2.76 ± .632	4.367	
Days to pollen maturity	-1.00 ± .327	3.058		-.62 ± .278	2.230		-1.12 ± .300	3.733	
Weight of stalk, grams	5.01 ± 2.210	2.267		-7.02 ± 2.118	3.314		-4.52 ± 3.389	1.892	
Weight of grain, grams	2.46 ± 2.321	1.060		-.24 ± 1.905	1.26		1.47 ± 2.180	.674	
Weight of cob, grams	1.46 ± 1.916	.762		-.39 ± 1.591	.245		.34 ± 1.855	.188	
Average length of internodes, inches	.76 ± .623	1.220		-.68 ± .533	1.276		-.30 ± .603	.497	
	C			C			C		
Number of nodes	-1.39 ± .634	2.192		-1.24 ± .601	2.063		-1.40 ± .603	2.846	
Circumference of stalk, inches	.03 ± .711	1.042		-.41 ± .657	.624		1.78 ± .522	3.410	
Height of stalk, inches	1.02 ± .834	1.223		-.60 ± .749	.801		2.76 ± .632	4.367	
Days to pollen maturity	-1.58 ± .408	3.873		-1.08 ± .393	2.738		-1.12 ± .300	3.733	
Weight of stalk, grams	-11.15 ± 3.539	3.151		-13.65 ± 3.362	4.060		-4.52 ± 3.389	1.892	
Weight of grain, grams	-9.89 ± 3.459	2.859		-11.12 ± 3.293	3.377		1.47 ± 2.180	.674	
Weight of cob, grams	-7.23 ± 2.712	2.666		-7.96 ± 2.574	3.092		.34 ± 1.855	.188	
Average length of internodes, inches	.94 ± .707	1.330		.56 ± .641	.874		-.30 ± .603	.497	
	C			C			C		

Table 21 (Continued).—Showing comparison of the different means, standard deviations and coefficients of variation.

Characters	Cornell No. 12 minus				F_1 Hybrid minus F_2 Hybrid	
	F_1 Hybrid		F_2 Hybrid		Difference	D/E
	Difference	D/E	Difference	D/E		
Number of nodes	M	5.057	M	16.231	M	20.769
Circumference of stalk, inches	—531 ± 105	2.526	1,899 ± 117	11.167	2,430 ± .117	14.364
Height of stalk, inches	—943 ± 019	12.866	2,683 ± .024	9.088	.316 ± .022	19.809
Days to pollen maturity	—926 ± 721	3.795	7,370 ± .866	248	1,288 ± .451	22.856
Weight of stalk, grams	—1,404 ± .370	11.364	35,116 ± .468	15.002	69,575 ± 3,044	26,278
Weight of grain, grams	—34,125 ± 3,003	5.819	35,450 ± 2,363	20.241	117,200 ± 4,460	20,202
Weight of cob, grams	—29,050 ± 4,992	7.345	88,150 ± 4,355	13.356	16,525 ± .818	.156
Average length of internodes, inches	—5,920 ± .806	5.891	10,605 ± .794	4.906	.010 ± .064	
	—324 ± .055		—314 ± .064			
Characters	σ		σ		σ	
Number of nodes	—207 ± .074	2.797	.056 ± .082	.683	.263 ± .082	3.207
Circumference of stalk, inches	.018 ± .014	1.286	.009 ± .017	.529	—,009 ± .016	.563
Height of stalk, inches	—1,460 ± .510	2.863	—,805 ± .612	1.315	.655 ± .611	1.072
Days to pollen maturity	—180 ± .261	.690	—,432 ± .331	1.305	—,252 ± .319	.790
Weight of stalk, grams	—23,050 ± 2,124	10.852	4,825 ± 1,671	2.887	27,875 ± 2,153	12.947
Weight of grain, grams	—12,850 ± 3,530	3.640	24,075 ± 3,079	7.819	36,925 ± 3,153	11.711
Weight of cob, grams	—2,325 ± .570	4.079	1,745 ± .562	3.105	4,070 ± .578	7.042
Average length of internodes, inches	—105 ± .039	2.692	—,024 ± .046	.522	.081 ± .045	1.800
Characters	C		C		C	
Number of nodes	—1.10 ± .538	2.045	—1.09 ± .671	1.624	.01 ± .663	.015
Circumference of stalk, inches	.89 ± .548	1.624	—,86 ± .730	1.178	—1.75 ± .677	2.585
Height of stalk, inches	—,49 ± .595	.824	—2.23 ± .806	2.767	—1.74 ± .791	2.228
Days to pollen maturity	—,12 ± .352	.341	—,58 ± .448	1.295	—,46 ± .429	1.072
Weight of stalk, grams	—9.53 ± 2,889	3.989	—16.16 ± 3,539	4.566	—6.63 ± 3,653	1.815
Weight of grain, grams	—,99 ± 2,284	433	—12.35 ± 3,525	3.504	—11.36 ± 3,435	3.307
Weight of cob, grams	—1.12 ± 1.914	.585	—8.69 ± 2,786	3.119	—7.57 ± 2,711	2.792
Average length of internodes, inches	—1.06 ± .633	1.675	.18 ± .733	.246	1.24 ± .716	1.732

RESULTS

Alvord's Dent X Cornell No. 12.—The means, standard deviations and coefficients of variation for the P_1 , F_1 and F_2 generations of the cross, Alvord's Dent X Cornell No. 12, are given in Table 19. The coefficients of correlation between pollen maturity, subject, and the other characters, relative; and weight and grain per stalk, subject, and the other characters, relative, are given in Table 20.

Comparison of the Constants of Variation.—A comparison of the means, standard deviations, and coefficients of variation is given in Table 21.

Comparison of the Means.—It will be seen from this comparison that the two parents show significant differences in the means for all the characters under consideration except circumference of stalk and length of internodes. The differences are in favor of Cornell No. 12 in all instances except length of internodes. In all instances the means of the F_1 hybrid generation are decidedly greater than those of the F_2 hybrid generation. The difference is very pronounced in yield per stalk which amounts to 117.200 ± 4.460 grams. The F_1 hybrid plants matured pollen $1.288 \pm .451$ days later, on the average, than did the F_2 hybrid plants.

The F_1 hybrid plants have mean values significantly higher in all instances than those of the average of the parents. In only two instances the F_2 hybrid plants show differences greater than the average of the parents. The F_1 hybrid generation mean values are markedly greater in every instance than those of Cornell No. 12. The Cornell No. 12 variety values are greater in all cases than those of the F_2 hybrid generation with exception of days to pollen maturity and average length of internodes.

The results obtained show that the F_1 hybrid generation plants possess mean values greater than the F_2 hybrid generation or those of either parent. However, the values for the F_2 hybrid generation are usually less than those of either parent. The decrease of the mean of the hybrid characters from greater than to less than the parental values in two years is very pronounced.

Comparison of the Standard Deviations.—A comparison of the standard deviations, Table 21, indicate that the characters of Cornell No. 12 are more variable than those of Alvord's Dent. The F_1 hybrid plants are decidedly more variable in four cases than the F_2 hybrid plants, while in the other instances the differences are not great. The F_1 hybrid generation plants are more variable than those of the average of the parents, while the F_2 hybrid plants are on the whole less variable. In the latter case the difference is marked in one instance only, weight of grain, the average of the parents being more variable. The F_1 hybrid is decidedly more variable in four characters than the average of the parents. The F_1 hybrid plants are significantly more variable in five cases than Alvord's Dent and those are the only pronounced differences. The differences between the F_2 hybrid generation plants and the Alvord's Dent variety are decided in only one instance, days to pollen maturity. Here the F_2 hybrid is more variable, the difference being $1.336 \pm .299$ days. The F_1 hybrid plants are significantly more variable in three cases than the Cornell No. 12 variety. These are the only three cases of pronounced differences. The F_2 hybrid plants exhibit significant differences from the Cornell No. 12 variety in one instance, weight of grain. Here the variety is more variable.

Comparisons of the Coefficients of Variation.—The results of Table 19 in regard to the coefficients of variation, show that the most variable characters are weight of stalk, weight of grain, and weight of cob. A comparison of the coefficients of variation for the different generations are given in Table 21.

Coefficients of Correlation.—It may be seen in Table 20 that a significant, positive correlation exists between the number of nodes per stalk and pollen maturity. It is interesting to note that this is the only one of the characters studied that shows a marked positive correlation with pollen maturity. With all the other characters there is either a negative correlation or a very slight positive one. Previous work shows a negative correlation to exist between yield per plant and days to tasseling and to silking. There is also a negative correlation between final maturity and tasseling and silking, but a rather high positive correlation between final maturity and yield. Probably pollen maturity is negatively correlated with final maturity. If pollen maturity is negatively correlated with final maturity, then, pollen maturity does not give a true indication of final maturity. Since final maturity shows a decided positive correlation with yield, if pollen maturity is negatively correlated with final maturity, it is to be expected that yield will show a positive correlation with those characters exhibiting a negative correlation with pollen maturity. This latter correlation has been found to exist.

The results presented in Table 20 show that yield is significantly and positively correlated with all the characters studied except pollen maturity. This fact holds true for both parents and in both of the hybrid generations. These coefficients of correlation indicate that high yielding plants possess a large number of nodes, have a large stalk circumference, are tall, possess heavy stalks, have large cobs, have long internodes, and mature their pollen early.

Comparison of the Correlations Between Pollen Maturity and Other Characters.—A comparison of the various coefficients of correlation calculated are shown in Table 22. When pollen maturity, subject, has been correlated with certain characters, relative, the only important difference between the coefficients in the F_1 and F_2 hybrid generations is in case of weight of stalk. In this instance the difference is $-.514 \pm .081$ in favor of the F_2 generation. Here the constant is 6.346 times greater than the probable error. In three of the seven instances there are marked differences between the two parents so far as the coefficients are concerned. A comparison of the F_1 and F_2 hybrid generations with the average of the parents shows decided difference in two cases when compared with the F_1 hybrid generation and none when compared with the F_2 hybrid generation. A comparison of the hybrid generations with Alvord's Dent shows significant differences in three instances when the F_1 hybrid generation is used in the comparison, and none when the F_2 hybrid is used. A comparison of the hybrid generations with Cornell No. 12 shows the coefficients of correlation of the F_1 hybrids to be significantly different in one instance only. In no case is the difference marked when compared with the F_2 generation.

The results so far secured lead to the belief that the various characters studied show about the same degree of correlation with pollen maturity in the P , F_1 and F_2 generations. However, there is some variation.

Comparison of the Correlations Between Weight of Grain Per Stalk and Other Characters.—Where weight of grain per stalk, subject, has been correlated with various characters, relative, there exists no significant differences between the values of the coefficients of correlation in the F_1 and F_2 hybrid generations. Decided differences exist in three instances between the parents. These are where yield has been correlated with pollen maturity, weight of cob, and average length of internodes. A comparison of the average of the parents with the F_1 hybrid generation shows important differences in two instances; number of nodes and weight of stalk, both being in favor of the average of the parents. In case of the F_2 generation a decided difference exists in one instance only, number of nodes, which is in favor of the average of the parents. Where the values of the coefficients of correlation secured

Table 22.—Showing comparison of the different correlation coefficients.

	Alvord's Dent <i>minus</i> Cornell No. 12		Average of Alvord's Dent and Cornell No. 12 <i>minus</i>				Alvord's Dent <i>minus</i>			
	Difference		F ₁ Hybrid		F ₂ Hybrid		F ₁ Hybrid		F ₂ Hybrid	
			Difference	D/E	Difference	D/E	Difference	D/E	Difference	D/E
Days to pollen maturity, subject, correlated with										
Number of nodes	.134 ± .068	1.971	-.066 ± .053	1.245	-.033 ± .071	.465	.001 ± .059	.017	.034 ± .076	.447
Circumference of stalk, inches.....	.058 ± .072	.806	-.045 ± .059	.763	.043 ± .076	.366	-.016 ± .067	.239	.072 ± .083	.867
Height of stalk, inches	.293 ± .072	4.069	.036 ± .061	.590	.026 ± .080	.325	.189 ± .067	2.716	.172 ± .085	2.024
Days to pollen maturity										
Weight of stalk, grams	.163 ± .074	2.203	.425 ± .053	8.019	-.089 ± .080	1.113	.507 ± .062	8.177	-.007 ± .086	.081
Weight of grain, grams	.292 ± .072	4.056	.066 ± .059	1.438	.081 ± .078	1.038	.232 ± .067	3.463	.227 ± .084	2.702
Weight of cob, grams	.180 ± .073	2.466	.057 ± .059	9.661	-.029 ± .080	.363	.147 ± .067	2.194	.061 ± .086	.709
Average length of internodes, inches.....	.225 ± .072	3.125	.144 ± .057	2.526	.093 ± .076	1.224	.257 ± .065	3.954	.206 ± .082	2.512
Weight of grain per stalk, subject, correlated with										
Number of nodes	-.036 ± .059	.610	.254 ± .054	4.704	.302 ± .075	4.027	.236 ± .060	3.933	.284 ± .079	3.595
Circumference of stalk, inches.....	-.140 ± .050	2.800	.030 ± .043	.698	-.094 ± .048	1.958	-.040 ± .051	.784	-.164 ± .055	2.982
Height of stalk, inches	.088 ± .041	2.146	.102 ± .038	2.684	.114 ± .053	2.151	.146 ± .040	3.650	.158 ± .054	2.926
Days to pollen maturity	.292 ± .072	4.056	.086 ± .059	1.453	.081 ± .078	1.038	.232 ± .067	3.463	.227 ± .084	2.702
Weight of stalk, grams	.013 ± .040	.325	.129 ± .039	3.308	.100 ± .051	1.961	.135 ± .042	3.214	.106 ± .053	2.000
Weight of grain, grams										
Weight of cob, grams	-.121 ± .027	4.481	.037 ± .024	1.542	.024 ± .031	.774	-.024 ± .030	.800	-.037 ± .036	1.028
Average length of internodes, inches.....	.299 ± .064	4.672	.008 ± .051	.157	-.154 ± .060	2.567	.157 ± .055	2.855	-.005 ± .063	.079

Table 22 (Continued).—Showing comparison of the different correlation coefficients.

	Cornell No. 12 minus				F ₁ Hybrid minus F ₂ Hybrid	
	F ₁ Hybrid		F ₂ Hybrid		Difference	D/E
	Difference	D/E	Difference	D/E		
Days to pollen maturity, subject, correlated with						
Number of nodes	-.133 ± .068	1.956	-.100 ± .083	1.205	.033 ± .076	.434
Circumference of stalk, inches	-.074 ± .072	1.028	.014 ± .087	.161	-.088 ± .083	1.060
Height of stalk, inches	-.111 ± .074	1.500	-.121 ± .090	1.344	-.010 ± .086	.116
Days to pollen maturity						
Weight of stalk, grams	.344 ± .068	5.059	-.170 ± .090	1.889	-.514 ± .081	6.346
Weight of grain, grams	-.060 ± .071	.845	-.065 ± .087	.747	-.005 ± .083	.060
Weight of cob, grams	-.033 ± .072	.458	-.119 ± .090	1.322	-.086 ± .085	1.012
Average length of internodes, inches	.032 ± .069	.464	-.019 ± .085	.224	-.051 ± .080	.638
Weight of grain per stalk, subject, correlated with						
Number of nodes	.272 ± .064	4.250	.320 ± .082	3.902	.048 ± .083	.578
Circumference of stalk, inches	.100 ± .049	2.041	-.024 ± .053	.453	-.124 ± .054	2.296
Height of stalk, inches	.058 ± .047	1.234	.070 ± .060	1.167	.012 ± .059	.203
Days to pollen maturity	-.060 ± .071	.845	-.065 ± .087	.747	.005 ± .083	.060
Weight of stalk, grams	.122 ± .046	2.652	.093 ± .056	1.661	-.029 ± .053	.500
Weight of grain, grams	.097 ± .026	3.731	.084 ± .033	2.545	-.013 ± .036	.361
Average length of internodes, inches	-.142 ± .063	2.088	-.304 ± .075	4.053	-.162 ± .067	2.418

with Alvord's Dent are compared with those of the F_1 generation four suggestive differences are found. In case of the F_2 hybrid generation only one important difference exists. A comparison of these values in the F_1 and F_2 hybrid generations with those of Cornell No. 12, shows two significant differences in case of both F_1 and F_2 hybrid generations. It will be found that the coefficient of correlation of weight of grain per stalk with number of nodes is markedly greater in case of the parents than in the hybrid generations in all instances but the difference between the parents is not pronounced.

These results indicate that various characters studied show about the same degree of correlation with weight of grain per stalk in the P_1 , F_1 and F_2 generations. However, there is some variation.

Narrow Leaf X Cornell No. 12.—The means, standard deviations, and coefficients of variation for the P_1 , F_1 and F_2 generations of the cross Narrow Leaf X Cornell No. 12 are given in Table 23. The coefficients of correlation for these same generations are given in Table 24. The weight of grain per stalk, subject, has been correlated with various characters, relative. The coefficients of correlation obtained with the Narrow Leaf variety are small with the exception of the one with weight of cob. The coefficient in this instance is $.618 \pm .047$. The coefficients in case of the Cornell No. 12 variety are large and positive in every instance. It will be seen from Table 24 that the coefficients are positive in all instances in each generation.

Comparison of the Constants of Variation.—A comparison of the means, standard deviations, and coefficients of variation are given in Table 25.

Comparison of the Means.—The mean values of the Cornell No. 12 variety are significantly greater than those of the Narrow Leaf variety in four of the instances. In the other instance the reverse is true. The F_1 hybrid values are decidedly greater in every case than those of the F_2 hybrid. The mean values for the average of the parents are markedly less in every case than those of the F_1 hybrid, but significantly greater in three instances than the F_2 hybrid, while in the case of the F_2 hybrid the remaining two differences are not pronounced. The Narrow Leaf variety mean values are much less in every instance than those of the F_1 hybrid.

This condition holds for three cases when the F_2 hybrid is compared with the Narrow Leaf variety. In the other two instances the differences are not great. The F_1 hybrid values are significantly greater in two instances than those of the Cornell No. 12, while in two instances the reverse is true. In the remaining case the difference is not great. The F_2 hybrid mean values are much less in every instance save the length of leaf. In this latter instance the difference is not pronounced.

In the Alvord's Dent—Cornell No. 12 cross the F_2 hybrid generation mean values were decidedly lower than those of either parent in practically all instances. This same condition holds with the Narrow Leaf—Cornell No. 12 cross so far as the latter variety is concerned, but not for the former variety. The lack of agreement in case of the Narrow Leaf variety may be due to the fact that the plants became badly affected with rust (*Puccinia sorghi*) in the latter part of the season.

Comparison of the Standard Deviations.—A comparison of the standard deviations in Table 25, shows that the Cornell No. 12 variety characters are more variable than those of the Narrow Leaf variety. Also the F_1 hybrid plants are more variable than the F_2 hybrid plants in three of the five instances. The F_1 hybrid is more variable, on the whole, than the average of the two parents, while the reverse is true in regard to the F_2 hybrid. The Narrow Leaf variety is less variable than either the F_1 hybrid or F_2 hybrid. The Cornell No. 12 variety is, in the main, more variable than either the F_1 hybrid or the F_2 hybrid.

Table 23.—Showing the means, standard deviation and coefficients of variation.

Characters	Narrow Leaf	Cornell No. 12	Narrow Leaf and Cornell No. 12 (Average)	Narrow Leaf X Cornell No. 12, F ₁ Hybrid	Narrow Leaf X Cornell No. 12, F ₂ Hybrid
	M	M	M	M	M
Length of leaf, inches.....	26.126 ± .189	25.216 ± .131	25.671 ± .108	27.814 ± .126	25.454 ± .174
Width of leaf, inches.....	1.815 ± .014	3.156 ± .020	2.486 ± .011	2.722 ± .014	2.414 ± .024
Weight of stalk, grams.....	61.550 ± 1.919	93.050 ± 1.698	77.300 ± 1.272	104.575 ± 2.817	58.625 ± 1.796
Weight of grain, grams.....	32.500 ± 1.503	178.125 ± 2.994	105.313 ± 1.344	161.750 ± 2.607	82.600 ± 2.179
Weight of cob, grams.....	11.935 ± .413	32.470 ± .544	22.203 ± .329	34.115 ± .619	18.065 ± .393
	σ	σ	σ	σ	σ
Length of leaf, inches.....	2.506 ± .134	2.580 ± .093	2.543 ± .076	2.418 ± .089	2.544 ± .123
Width of leaf, inches.....	.187 ± .010	.402 ± .014	.295 ± .013	.276 ± .010	.347 ± .017
Weight of stalk, grams.....	25.450 ± 1.357	33.400 ± 1.201	29.425 ± .899	53.975 ± 1.992	26.225 ± 1.270
Weight of grain, grams.....	19.925 ± 1.062	58.900 ± 2.117	39.413 ± .950	49.950 ± 1.844	31.825 ± 1.541
Weight of cob, grams.....	5.475 ± .292	10.695 ± .384	8.085 ± .232	11.855 ± .438	5.740 ± .278
	C	C	C	C	C
Length of leaf, inches.....	9.59 ± .511	10.23 ± .372	9.91 ± .301	8.69 ± .321	9.99 ± .484
Width of leaf, inches.....	10.30 ± .555	12.74 ± .465	11.52 ± .356	10.14 ± .378	14.37 ± .710
Weight of stalk, grams.....	41.35 ± 2.554	35.89 ± 1.447	38.62 ± 1.259	51.61 ± 2.358	44.73 ± 2.563
Weight of grain, grams.....	61.31 ± 4.327	33.07 ± 1.313	47.19 ± 1.256	30.88 ± 1.244	38.53 ± 2.125
Weight of cob, grams.....	45.87 ± 2.915	32.94 ± 1.306	39.41 ± 1.192	34.75 ± 1.429	31.77 ± 1.687

Table 24.—Showing the coefficients of correlation.

Weight of grain per stalk, subject, correlated with	Narrow Leaf	Cornell No. 12	Narrow Leaf and Cornell No. 12 (Average)	Narrow Leaf X Cornell No. 12, F ₁ Hybrid	Narrow Leaf X Cornell No. 12, F ₂ Hybrid
Length of leaf, inches.....	.0001 ± .075	.582 ± .034	.291 ± .031	.179 ± .051	.314 ± .062
Width of leaf, inches.....	.109 ± .075	.659 ± .029	.384 ± .027	.442 ± .042	.648 ± .040
Weight of stalk, grams.....	.052 ± .075	.682 ± .027	.367 ± .025	.456 ± .041	.371 ± .059
Weight of grain, grams.....					
Weight of cob, grams.....	.618 ± .047	.836 ± .015	.727 ± .014	.673 ± .029	.721 ± .033

Table 25.—Showing comparison of the different means, standard deviations and coefficients of variation.

Characters	Narrow Leaf minus Cornell No. 12		Average of Narrow Leaf and Cornell No. 12 minus				Narrow Leaf minus			
	F ₁ Hybrid		F ₁ Hybrid		F ₂ Hybrid		F ₁ Hybrid		F ₂ Hybrid	
	Difference	D/E	Difference	D/E	Difference	D/E	Difference	D/E	Difference	D/E
Length of leaf, inches	M		M		M		M		M	
Width of leaf, inches	.910 ± .230	3.957	-.2143 ± .166	12.910	.217 ± .205	1.059	-.1.688 ± .227	7.436	.672 ± .257	2.615
Weight of stalk, grams	-1.341 ± .024	55.875	-.236 ± .018	13.111	.072 ± .026	2.769	-.907 ± .020	4.535	-.599 ± .028	21.393
Weight of grain, grams	-31.500 ± 2.562	12.295	-.27.275 ± 3.091	8.824	18.675 ± 2.201	8.485	-43.025 ± 3.409	12.621	2.925 ± 2.628	1.113
Weight of cob, grams	-145.625 ± 3.350	43.470	-56.437 ± 2.933	19.242	22.713 ± 2.560	8.872	-129.250 ± 3.009	42.954	-50.100 ± 2.647	18.927
	-20.535 ± .683	30.066	-11.912 ± .701	16.993	4.133 ± .513	8.066	-22.180 ± .744	29.812	-6.130 ± .570	10.754
Characters	σ		σ		σ		σ		σ	
Length of leaf, inches	-.074 ± .163	.454	.125 ± .117	1.068	-.001 ± .145	.007	.088 ± .161	.547	-.038 ± .182	.209
Width of leaf, inches	-.215 ± .017	12.647	-.019 ± .016	1.188	-.032 ± .021	2.476	-.089 ± .014	6.357	-.160 ± .020	8.000
Weight of stalk, grams	-7.950 ± 1.812	4.387	-24.550 ± 2.185	11.236	3.200 ± 1.556	2.057	-28.532 ± 2.410	11.836	-.775 ± 1.859	.417
Weight of grain, grams	-38.975 ± 3.368	16.459	-10.537 ± 2.074	5.081	7.598 ± .810	4.192	-30.025 ± 2.128	14.109	-11.900 ± 1.872	6.357
Weight of cob, grams	-5.220 ± .482	10.830	-3.770 ± .496	7.601	2.345 ± .362	6.473	-6.380 ± .526	12.129	-.265 ± .403	.658
Characters	C		C		C		C		C	
Length of leaf, inches	-.64 ± .632	1.013	1.22 ± .440	2.773	-.08 ± .570	.140	.90 ± .603	1.493	-.40 ± .704	.568
Width of leaf, inches	-2.44 ± .724	3.370	1.38 ± .519	2.659	-2.85 ± .794	3.589	.16 ± .671	.238	-4.07 ± .901	4.517
Weight of stalk, grams	5.46 ± 2.935	1.860	-12.99 ± 2.673	4.860	-6.11 ± 2.856	2.139	-10.26 ± 3.476	2.952	-3.38 ± 3.618	.934
Weight of grain, grams	28.24 ± 4.522	6.245	16.31 ± 1.768	9.225	8.66 ± 2.468	3.509	30.43 ± 4.502	6.759	22.78 ± 4.821	4.725
Weight of cob, grams	12.93 ± 3.194	4.048	4.66 ± 1.861	2.504	7.64 ± 2.066	3.698	11.12 ± 3.246	3.426	14.10 ± 3.368	4.186

Table 25 (Continued).—Showing comparison of the different means, standard deviations and coefficients of variation.

Cornell No. 12 minus						
Characters	F ₁ Hybrid		F ₂ Hybrid		F ₁ Hybrid minus F ₂ Hybrid	
	Difference	D/E	Difference	D/E	Difference	D/E
	M		M		M	
Length of leaf, inches	-2.598 ± .182	14.275	-238 ± .218	1.092	2.360 ± .215	10.977
Width of leaf, inches	.434 ± .024	18.083	.742 ± .031	23.935	.308 ± .028	11.000
Weight of stalk, grams	-11.525 ± 3.289	3.504	34.425 ± 2.472	13.926	45.950 ± 3.341	13.753
Weight of grain, grams	16.375 ± 3.970	4.125	95.525 ± 3.703	25.797	79.150 ± 3.396	23.293
Weight of cob, grams	-1.645 ± .824	1.996	14.405 ± .671	21.468	16.050 ± .733	21.896
Characters	σ		σ		σ	
Length of leaf, inches	.162 ± .129	1.256	.036 ± .154	.234	-.126 ± .152	.829
Width of leaf, inches	.126 ± .017	7.412	.055 ± .022	2.500	-.071 ± .020	3.550
Weight of stalk, grams	-20.575 ± 2.326	8.846	7.175 ± 1.748	4.105	27.750 ± 2.362	11.749
Weight of grain, grams	8.950 ± 2.807	3.188	27.075 ± 2.618	10.342	18.125 ± 2.403	7.543
Weight of cob, grams	-1.160 ± .582	1.993	4.955 ± .474	10.454	6.115 ± .519	11.782
Characters	C		C		C	
Length of leaf, inches	1.54 ± .491	3.136	.24 ± .610	.393	1.30 ± .591	2.238
Width of leaf, inches	2.60 ± .599	4.341	-1.63 ± .849	1.920	-4.23 ± .804	5.261
Weight of stalk, grams	-15.72 ± 2.767	5.681	-8.84 ± 2.943	3.004	6.88 ± 3.483	1.975
Weight of grain, grams	2.19 ± 1.809	1.211	-5.46 ± 2.498	2.186	-7.65 ± 2.462	3.107
Weight of cob, grams	-1.81 ± 1.936	.935	1.17 ± 2.133	.549	2.98 ± 2.211	1.348

Comparison of the Coefficients of Variation.—The most variable characters as shown by the coefficients of variation, Table 23, are weight of stalk, weight of grain, and weight of cob. These were the characters found to be most variable in the Alvord's Dent=Cornell No. 12 cross. A comparison of the coefficients of variation for the P_1 , F_1 and F_2 generations are given in table 25.

Comparison of the Coefficients of Correlation.—A comparison of the coefficients of correlation are shown in Table 26. The coefficients for the Cornell No. 12 variety are markedly greater than those of the Narrow Leaf variety in every case. The F_2 hybrid is significantly greater than the F_1 hybrid in one case, weight of grain per stalk and width of leaf. In the other cases the differences are not pronounced. The value of the coefficients for the average of the parents is significantly greater in one instance than the F_1 hybrid value. In one case the F_1 hybrid is significantly greater than the average of the parent values and likewise for the F_2 hybrid value. The correlation values for the Narrow Leaf variety are decidedly less than those of the F_1 hybrid in two instances and of those of the F_2 hybrid in three instances. The Cornell No. 12 variety correlation values excel those of the F_1 and F_2 hybrids in all four instances.

The results of this cross indicate that there is a closer correlation between weight of grain per stalk and length of leaf, width of leaf, weight of stalk, and weight of cob in the Cornell No. 12 variety than in the Narrow Leaf variety or in the F_1 and F_2 generation hybrids resulting from the crossing of the two varieties. This condition does not apparently exist in the Alvord's Dent-Cornell No. 12 cross. In the latter cross there were no consistent differences in the coefficients of correlation in the several generations or between the parent varieties.

SUMMARY

The inheritance of certain characters in the F_1 and F_2 generations of two corn hybrids, Alvord's Dent X Cornell No. 12; and Narrow Leaf X Cornell No. 12, as well as that of the corresponding characters of the parents was studied.

The mean values for the various characters studied in the Alvord's Dent-Cornell No. 12 cross are greater in practically all instances in the F_1 generation than in the P_1 generation. In the case of the F_2 generation, the values are less than those of either parents.

The differences in the variability of the various characters in the several generations show no great consistency. This condition hold for both of the hybrids studied.

Days to pollen maturity shows a significant and positive correlation with number of nodes per plant in all generations studied. With all the other characters studied the correlation with pollen maturity is either negative or very slightly positive.

Weight of grain per stalk is significantly and positively correlated with all the characters studied with the exception of days to pollen maturity. This condition exists in the P_1 , F_1 and F_2 generations.

The results of this and other investigations indicate that late maturing, high yielding plants are those that tassel, silk and mature pollen early in the period of growth.

The results indicate, in case of the Alvord's Dent-Cornell No. 12 hybrid, that about the same degree of correlation exists between the characters when correlated with either pollen maturity or yield per plant in the P_1 , F_1 and F_2 generations.

In the case of the Narrow Leaf-Cornell No. 12 hybrid the correlation coefficients between weight of grain per stalk and various characters are much more significant

Table 26.—Showing comparison of the different coefficients of correlation.

	Narrow Leaf <i>minus</i> Cornell No. 12		Average of Narrow Leaf and Cornell No. 12 <i>minus</i>		Narrow Leaf <i>minus</i>			
					F ₁ Hybrid	F ₂ Hybrid	F ₁ Hybrid	F ₂ Hybrid
	Difference	D/E	Difference	D/E	Difference	D/E	Difference	D/E
Weight of grain per stalk, subject, correlated with								
Length of leaf, inches.....	.582 ± .082	7.098	.112 ± .060	18.667	-.179 ± .091	1.967	-.314 ± .097	3.237
Width of leaf, inches.....	.550 ± .080	6.875	-.058 ± .050	11.600	-.333 ± .086	3.872	-.539 ± .085	6.341
Weight of stalk, grams.....	-.630 ± .080	7.875	-.089 ± .048	1.854	-.404 ± .065	4.753	-.319 ± .095	3.358
Weight of grain, grams.....								
Weight of cob, grams.....	-.218 ± .049	4.449	.054 ± .032	1.638	-.055 ± .055	1.000	-.103 ± .057	1.807

Table 26 (Continued).—Showing comparison of the different coefficients of correlation.

	Cornell No. 12 <i>minus</i>				F ₁ Hybrid <i>minus</i> F ₂ Hybrid			
	F ₁ Hybrid		F ₂ Hybrid		F ₁ Hybrid		F ₂ Hybrid	
	Difference	D/E	Difference	D/E	Difference	D/E	Difference	D/E
Weight of grain per stalk, subject, correlated with								
Length of leaf, inches.....	.403 ± .061	6.607	.263 ± .063	4.254	-.135 ± .080	1.678	-.206 ± .058	3.552
Width of leaf, inches.....	.217 ± .051	4.255	.011 ± .049	.224	-.085 ± .072	1.181		
Weight of stalk, grams.....	.226 ± .049	4.612	.311 ± .065	4.785				
Weight of grain, grams.....								
Weight of cob, grams.....	.163 ± .033	4.939	.115 ± .036	3.194	-.048 ± .044	1.091		

for the Cornell No. 12 variety than for the Narrow Leaf variety. In every case, however, of the several generations the coefficients are positive and in most cases significant.

In the Narrow Leaf-Cornell No. 12 hybrid a closer correlation seems to exist between weight of grain per stalk and the various characters studied in the Cornell No. 12 variety than in the Narrow Leaf variety or in the F_1 and F_2 hybrid generations.

The mean values of the F_1 hybrid, Narrow Leaf-Cornell No. 12, are in practically all cases, greater than those of the F_2 hybrid or either parent. The F_2 hybrid values are less than those of the average of the parents; less than those of Cornell No. 12 with one exception; but greater in three instances than the Narrow Leaf values.

The most variable characters in both crosses are weight of stalk, weight of grain and weight of cob.

PART III

INHERITANCE OF CORRELATED CHARACTERS

In the course of the investigation as reported under Part I, a high degree of correlation was found between the yield per plant and circumference of stalk. The correlation was positive and indicated that plants with large circumferences yielded more than those with small circumferences. Should it be possible to determine the yielding capacity of plants by their circumference it would be of great practical importance. It is possible to determine the circumference before the plants tassel and silk and thus the control of parentage would be facilitated. Should seeds secured from large circumference plants yield greater than that from small plants, as the coefficient of correlation indicate they will, a means of selecting high yielding seed could be provided without conducting such tests as the ear-to-row test. In such an event much time would be saved.

The object of this phase of the investigation was, therefore, to study the influence of circumference of maize plants on the yielding ability of the seed produced.

MATERIAL AND METHODS

A number of plants of the Silver King variety of corn were measured just below the ear node shortly before silking and the circumferences determined. All plants having circumferences less than three inches were classed as small plants and those having circumferences three inches and greater were classed as large plants. There were 139 large plants obtained with an average circumference of 3.15 inches. The small circumference plants numbered 129 and their average circumference was 2.71 inches. All ears were covered with paper bags before silking and they remained covered until pollinated when the bags were removed to allow pollination after which the bags were replaced. The ears remained protected by bags until harvest. The tassels were enclosed within paper bags for at least twenty-four hours before the pollen was to be used.

When the ears of corn were ready to be pollinated the pollen was collected from the large circumference plants and the pollen thoroughly mixed; likewise the pollen from the small circumference plants. Thus there were two lots of mixed pollen. Some of the ears on the large circumference plants were pollinated with the mixed pollen from the large circumference plants and others with mixed pollen from the small circumference plants. In the case of the small circumference plants some of

the ears were pollinated with the mixed pollen from the small circumference plants and others with mixed pollen from the large circumference plants. Therefore, four kinds of ears were produced as follows:

1. Ears from large circumference plants pollinated with mixed pollen from large circumference plants.
2. Ears from large circumference plants pollinated with mixed pollen from small circumference plants.
3. Ears from small circumference plants pollinated with mixed pollen from small circumference plants.
4. Ears from small circumference plants pollinated with mixed pollen from large circumference plants.

Thus the ears under heading 1 and 3 may be classed as self-pollinated and those under headings 2 and 4 may be classed as cross-pollinated.

The yielding ability of ten ears of each group was determined by planting four rows from each ear. The rows from each ear were not planted consecutively but there were four series and each series contained a row planted from each ear together with the check rows. Every tenth row was planted with seed of the Silver King variety grown under similar conditions under which the large and small circumference plants were grown. These tenth rows served as checks. The crop was planted in hills 39.6 inches apart each way and twenty hills to the row. Thus, each row constituted 1/200 of an acre. A record was kept of the yield of shelled corn of each row.

The circumference of the plants used is shown in Table 27. The small circum-

Table 27.—The circumference of plants from which seed was selected for planting, and the type of pollination.

Type of pollination	Ear No.	Circumference of plants, inches	Type of pollination	Ear No.	Circumference of plants, inches
Large circumference plants—self pollinated	1	3.125	Small circumference plants—self pollinated	21	2.750
	2	3.250		22	2.625
	3	3.375		23	2.500
	4	3.375		24	2.500
	5	3.500		25	2.750
	6	4.000		26	2.750
	7	3.125		27	2.750
	8	3.375		28	2.750
	9	3.500		29	2.750
	10	3.250		30	2.625
Large circumference plants x small circumference plants	11	3.250	Small circumference plants x large circumference plants	31	2.500
	12	3.125		32	2.250
	13	3.250		33	2.500
	14	3.125		34	2.500
	15	3.125		35	2.500
	16	3.000		36	2.500
	17	3.250		37	2.750
	18	3.000		38	2.750
	19	3.125		39	2.750
	20	3.500		40	2.750

ference plants ranged from 2.25 inches to 2.75 inches, while the range of the large circumference plants was from 3 inches to 4 inches.

RESULTS

The yields of the various ears and the checks are shown in Table 28. The probable errors of the yields were determined by Bessel's formula. The formula is as follows: $E_m = \pm .6745 \frac{\sqrt{\sum d^2}}{\sqrt{n(n-1)}}$. In this formula d is the deviation of each individual from the average and n is the number of individuals averaged.

In order to determine the significance of the differences in yield of the different ears as compared with the checks the results have been compared by "Student's" and Bessel's methods and are shown in Table 29.

Table 28.—Yield of the different ears and the checks.

Kind of parent plants and type of pollination	Ear No.	Yield per row in bushels per acre				
		1	2	3	4	Average
Large circumference plants—self pollinated	1	47.32	57.45	44.64	39.29	45.43±1.59
	Check	58.48	68.75	43.75	50.00	55.25±3.66
	2	43.30	46.43	36.61	38.39	41.18±1.52
	Check	58.48	55.36	43.75	50.00	51.90±2.18
	3	57.14	57.59	44.64	26.79	46.54±4.88
	Check	58.48	55.36	43.75	33.04	47.66±3.92
	4	48.66	44.64	46.88	33.04	43.31±2.37
	Check	58.48	55.36	43.75	33.04	47.66±3.92
	5	43.30	53.57	34.82	33.93	41.41±3.08
	Check	58.48	55.36	43.75	33.04	47.66±3.92
	6	58.48	68.75	50.00	43.30	55.13±3.71
	Check	47.77	55.36	43.75	33.04	44.98±3.14
	7	44.64	59.82	35.27	37.95	44.42±3.71
	Check	47.77	55.36	51.34	33.04	46.88±3.28
	8	44.20	55.80	33.93	45.54	44.87±3.02
	Check	47.77	55.36	51.34	33.04	46.88±3.28
	9	59.82	56.25	37.95	54.02	52.01±3.26
	Check	47.77	55.36	51.34	33.04	46.88±3.28
	10	39.29	48.21	33.04	44.64	41.30±2.23
	Check	47.77	55.36	51.34	33.04	46.88±3.28
Large circumference plants x small circumference plants	11	41.07	42.41	42.86	39.29	41.41±.54
	Check	67.86	47.77	45.54	47.77	52.24±3.53
	12	58.48	60.71	44.64	49.55	53.35±2.54
	Check	67.86	47.77	45.54	47.77	52.24±3.53
	13	56.70	62.05	55.36	50.00	56.03±1.67
	Check	68.75	47.77	45.54	47.77	52.46±3.63
	14	52.68	44.20	38.84	44.64	45.09±1.92
	Check	63.75	47.77	50.00	47.77	53.57±3.39
	15	58.04	53.57	41.96	46.43	50.00±2.42
	Check	68.75	47.77	50.00	47.77	53.57±3.39
	16	63.39	50.89	45.09	44.64	51.00±2.95
	Check	68.75	47.77	50.00	47.77	53.57±3.43
	17	62.50	50.89	54.46	45.98	53.46±2.35
	Check	68.75	47.77	50.00	47.77	53.57±3.43
	18	53.13	50.89	48.66	48.21	50.22±.76
	Check	68.75	43.75	50.00	41.52	51.01±4.17
	19	49.11	46.43	50.00	41.52	46.77±1.29
	Check	68.75	43.75	50.00	41.52	51.01±4.17
	20	69.20	46.43	44.64	45.54	51.45±4.00
	Check	68.75	43.75	50.00	41.52	51.01±4.17

Table 28 (Continued).—Yield of the different ears and the checks.

Kind of parent plants and type of pollination	Ear No.	Yield per row in bushels per acre				
		1	2	3	4	Average
Small circumference plants—self pollinated	21	51.34	48.66	47.77	47.32	48.77±.61
	Check	47.77	58.48	48.21	33.04	46.88±3.53
	22	52.68	52.68	54.02	56.70	54.02±.64
	Check	47.77	58.48	48.21	50.89	51.34±1.67
	23	40.63	41.96	40.18	41.96	41.18±.31
	Check	47.77	58.48	48.21	50.89	51.34±1.67
	24	45.09	45.98	47.77	44.64	45.87±.47
	Check	47.77	58.48	48.21	50.89	51.34±1.67
	25	54.91	57.14	54.02	53.57	54.91±.53
	Check	53.57	58.48	48.21	50.89	52.79±1.48
	26	46.43	51.34	41.52	50.89	47.55±1.54
	Check	53.57	58.48	50.45	50.89	53.35±1.25
	27	49.11	55.36	48.21	40.63	48.33±2.04
	Check	53.57	58.48	50.45	50.89	53.35±1.25
	28	55.36	57.14	45.54	48.21	51.56±1.88
	Check	53.57	58.48	50.45	50.89	53.35±1.25
	29	59.82	43.30	44.64	46.88	48.66±2.56
	Check	53.57	58.48	50.45	50.89	53.35±1.25
	30	52.23	43.75	37.50	47.77	45.31±2.11
	Check	53.57	49.55	50.45	50.89	51.12±.58
Small circumference plants x large circumference plants	31	57.14	58.93	58.04	48.21	55.58±1.68
	Check	53.57	49.55	50.45	48.66	50.56±.72
	32	49.11	57.59	43.30	52.68	50.67±2.03
	Check	53.57	49.55	50.45	48.66	50.56±.72
	33	53.57	51.34	48.21	37.05	47.54±2.48
	Check	53.57	49.55	50.45	48.66	50.56±.72
	34	53.57	41.07	41.07	42.41	44.53±2.04
	Check	67.86	49.55	50.45	48.66	54.13±3.10
	35	60.27	50.15	48.66	44.64	51.01±2.24
	Check	67.86	49.55	45.54	48.66	52.90±3.41
	36	56.25	49.11	49.55	47.77	50.67±4.05
	Check	67.86	49.55	45.54	48.66	52.90±3.41
	37	54.91	52.68	50.89	39.29	49.44±2.35
	Check	67.86	49.55	45.54	48.66	52.90±3.41
	38	53.57	54.91	48.21	48.21	51.23±1.19
	Check	67.86	49.55	45.54	48.66	52.90±3.41
	39	66.96	54.02	57.14	45.19	55.80±3.04
	Check	67.86	47.77	45.54	48.66	52.46±3.49
	40	56.25	44.20	37.05	48.21	46.43±2.70
	Check	67.86	47.77	45.54	47.77	52.24±3.53

Table 29.—Differences between the yields of the different ears and the nearest checks according to Bessel's method and odds according to Bessel's and "Student's" methods.

Kind of parent plants and type of pollination	Ear No.	Gain per acre over nearest check		Odds as compared with nearest check according to	
		Difference	D/E	"Student's" method	Bessel's method
Large circumference plants—self pollinated	1	— 9.82±3.99	2.46	(—) 21.27:1	(—) 9.89:1
	2	—10.72±2.66	4.03	(—) 226.27:1	(—) 142.26:1
	3	— 1.12±6.26	.18	(—) 1.97:1	(—) <1:1
	4	— 4.35±4.58	.95	(—) 5.63:1	(—) <1:1
	5	— 6.25±4.99	1.25	(—) 10.01:1	(—) 1.63:1
	6	10.13±4.86	2.09	262.16:1	5.38:1
	7	— 2.46±4.95	.50	(—) 2.08:1	(—) <1:1
	8	— 2.01±4.46	.45	(—) 1.62:1	(—) <1:1
	9	5.13±4.62	1.11	2.72:1	1.18:1
	10	— 5.58±3.97	1.41	(—) 3.60:1	(—) 1.90:1
Large circumference plants x small circumference plants	11	—10.83±3.57	3.03	(—) 13.18:1	(—) 22.26:1
	12	1.11±4.35	.26	1.42:1	.36:1
	13	3.57±4.02	.89	2.46:1	<1:1
	14	— 8.48±3.90	2.17	(—) 5.16:1	(—) 6.26:1
	15	— 3.57±4.17	.86	(—) 3.94:1	(—) <1:1
	16	— 2.57±4.52	.57	(—) 6.13:1	(—) <1:1
	17	— .11±4.16	.03	(—) * :	(—) <1:1
	18	— .79±4.24	.19	(—) * :	(—) <1:1
	19	— 4.24±4.37	.97	(—) 3.20:1	(—) <1:1
	20	.44±5.78	.08	1.39:1	<1:1
Small circumference plants—self pollinated	21	1.89±3.58	.53	1.74:1	<1:1
	22	2.68±1.79	1.50	3.85:1	2.21:1
	23	—10.16±1.70	5.98	(—) 110.11:1	(—) 192.30:1
	24	— 5.47±1.73	3.16	(—) 14.48:1	(—) 31.36:1
	25	2.12±1.57	1.35	6.96:1	1.90:1
	26	— 5.80±1.93	2.93	(—) 31.38:1	(—) 18.80:1
	27	— 5.02±2.39	2.10	(—) 27.74:1	(—) 5.38:1
	28	— 1.79±2.26	.79	(—) 11.84:1	(—) <1:1
	29	— 4.69±2.85	1.65	(—) 4.52:1	(—) 2.98:1
	30	— 5.81±2.19	2.65	(—) 17.48:1	(—) 13.58:1
Small circumference plants x large circumference plants	31	5.02±1.83	2.74	17.76:1	13.58:1
	32	.11±2.15	.05	.13:1	<1:1
	33	— 3.02±2.58	1.17	(—) 4.23:1	(—) 1.39:1
	34	— 9.60±3.71	2.59	(—) 184.19:1	(—) 11.58:1
	35	— 1.89±4.08	.46	(—) 3.05:1	(—) <1:1
	36	— 2.23±5.29	.42	(—) 2.65:1	(—) <1:1
	37	— 3.46±4.14	.84	(—) 2.98:1	(—) <1:1
	38	— 1.67±3.61	.46	(—) 1.74:1	(—) <1:1
	39	3.34±4.63	.72	3.76:1	<1:1
	40	— 5.81±4.44	1.31	(—) 16.01:1	(—) 1.63:1

*The P values for these small differences are not given in "Student's" tables.

"Student's" method of analysis is described in Biometrika, volume 6, pages 1-25. An elaboration of this method appears in Biometrika, volume 11, pages 414-417. By this method pairs of observations are compared and the mean deviation and the standard deviation of the deviates computed. "Student's" Z value is found as follows: $Z = \frac{\text{mean}}{\text{standard deviation}}$. In volume 11 of Biometrika, tables of Z values will

be found from which the probability can be computed. From the probability or P value the odds can be determined.

When the probable errors have been determined by Bessel's formula the odds are calculated in the ordinary way after the difference between any two quantities has

been determined and the probable error of the difference found. In comparing two treatments the probable error of the difference is obtained by taking the square root of the sum of the squares of the probable errors of the two results. Thus, the formula is as follows: $E \text{ difference} = \sqrt{a^2 + b^2}$.

In the formula a and b represent the probable errors of the two results.

The next step is to divide the difference by the probable error of the difference and the result is expressed in Table 29 as D/E . From this quantity the odds can be determined. The work may be facilitated by using the tables prepared by Pearl and Miner (1914) which show the significance of a treatment increase or decrease in relation to the size of its probable error. It is generally assumed (Wood and Stratton, 1910) that odds of 30:1 or greater are significant. When the difference is 3.2 times its probable error the odds are 31.36:1.

The results in Table 29 indicate that the differences in yield between the checks and the various ears are very small. In only a few instances are the differences sufficiently great to be considered significant. In the case of practically all the differences, although usually small, they are in favor of the checks as indicated by the minus (—) signs.

According to "Student's" method there are five differences which may be considered significant. According to Bessel's method there are three instances of significant differences. In two of the three instances where a pronounced difference is indicated by Bessel's method marked differences are indicated by "Student's" method. It is generally considered better to use "Student's" method in preference to Bessel's method where it can be used. Where the experiment has been conducted so that it is feasible to compare two variates "Student's" method can be readily used. As a rule, in such instances the differences will appear to have greater significance when "Student's" method is used than when the data are treated by Bessel's formula. The advantage of "Student's" method is due to the fact that it recognizes the necessity of comparing the observations made under similar conditions and does not assume, as does Bessels' method, that there are absolute values in field trials from which all deviations are fluctuations due to errors of random sampling (Love and Brunson, 1924).

In consideration of the differences between the average yields of the different groups of ten ears it was found that the variations were not of sufficient magnitude to be significant. The average yield of the ears produced from large circumference plants which had been self-pollinated was 4.32 bushels less than the average yield of the ten ears produced from the large circumference plants which had been pollinated with pollen from the small circumference plants. According to "Student's" method the odds in this case were 26.40:1 and the difference was, therefore, not pronounced. The ten ears representing the small circumference plants which had been crossed with pollen from the large circumference plants yielded 1.67 bushels more on the average than the ten ears representing the small circumference plants which had been self-pollinated. This difference gives odds of 7.59:1, which is not large.

In comparing the average yield of the ten ears obtained from the self-pollinated large circumference plants with the average yield of the ten ears from the self-pollinated small circumference plants the difference is 3.06 bushels in favor of the self-pollinated small circumference plants. The odds in this case were 9.73:1 and the difference is not decided. The average yield of the ten ears of the small circumference plants crossed with the large circumference plants was .41 bushels greater than the average yield of the ten ears from the large circumference plants pollinated with pollen from the small circumference plants. The P value for this difference is not given in "Student's" tables but it is so small as to be obviously not important.

Thus, it seems that the seed from large circumference plants not only failed to give a significantly greater yield than ordinary field selected seed but there were no significant differences between the yields of the various groups of ears which were produced from plants variously pollinated.

SUMMARY

The results reported in Part III were secured from an investigation which was conducted for one year. Therefore, the results should not be considered conclusive. However, they are worthy of careful consideration and thought. The results secured indicate, under the conditions of the investigation, that the seed from large circumference stalks of maize is no better than ordinary field selected seed of the same variety. Apparently seed borne on small circumference stalks is neither inferior nor superior to ordinary field selected seed.

The differences in yield between seed produced by small circumference plants and by large circumference plants, whether the seed were self-pollinated or cross-pollinated, are so slight as not to be important.

It is to be remembered that previous results obtained indicated that corn plants with large circumferences yield more than those with small circumferences as the coefficient of correlation between weight of grain per stalk and circumference was $.653 \pm .020$. It seems, therefore, that it is important to determine whether the inter-relationship between characters will be inherited before attaching too much significance to their correlation. If the correlation of characters is to be of the greatest economic importance, it is necessary that the correlation be transmitted from one generation to another.

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